The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
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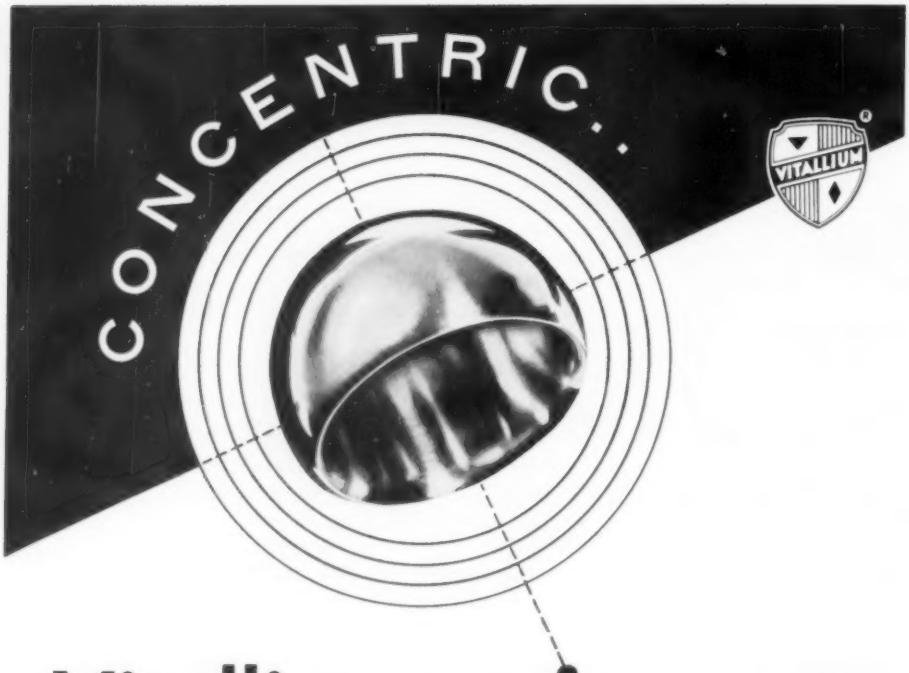

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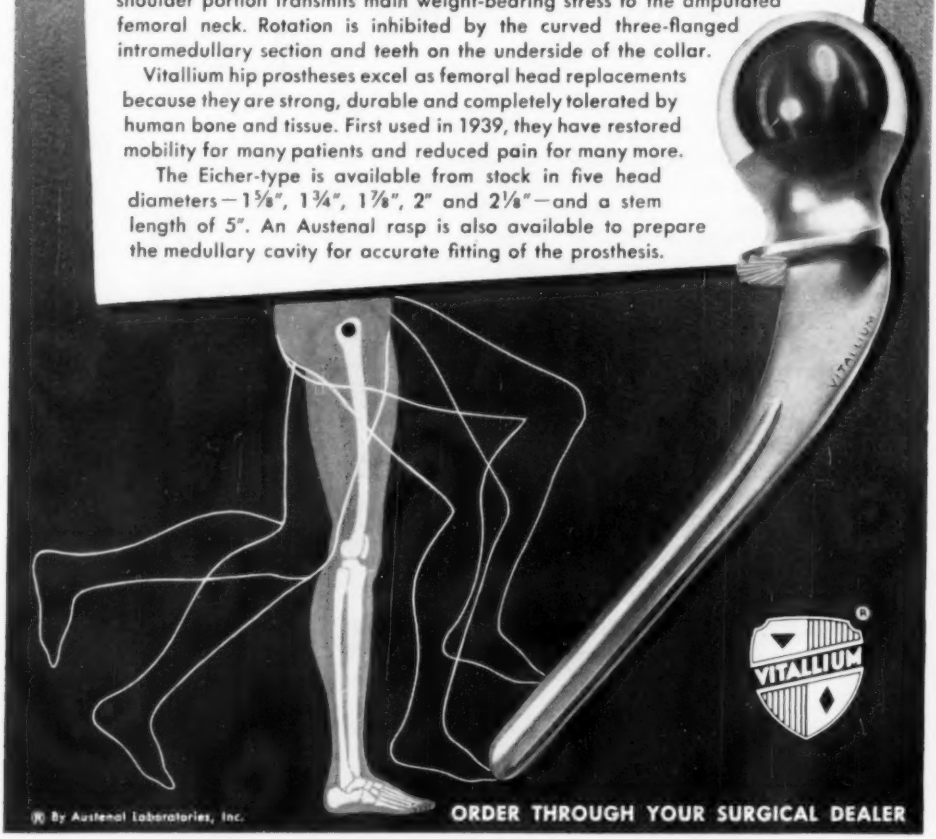

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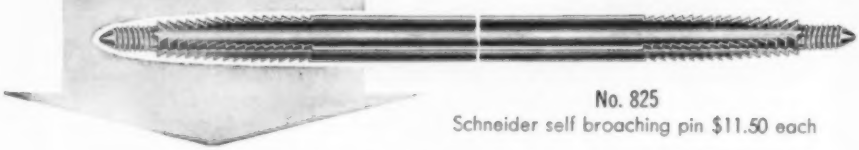

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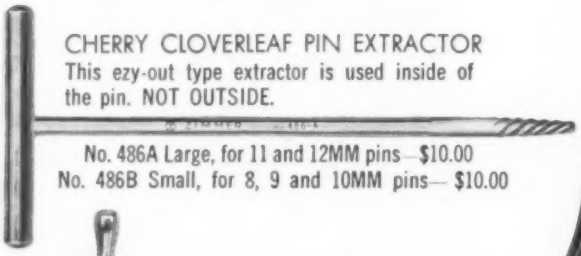

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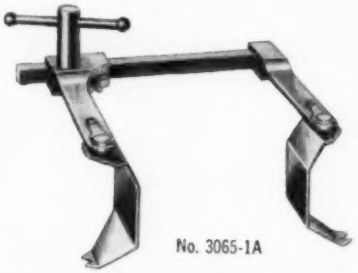

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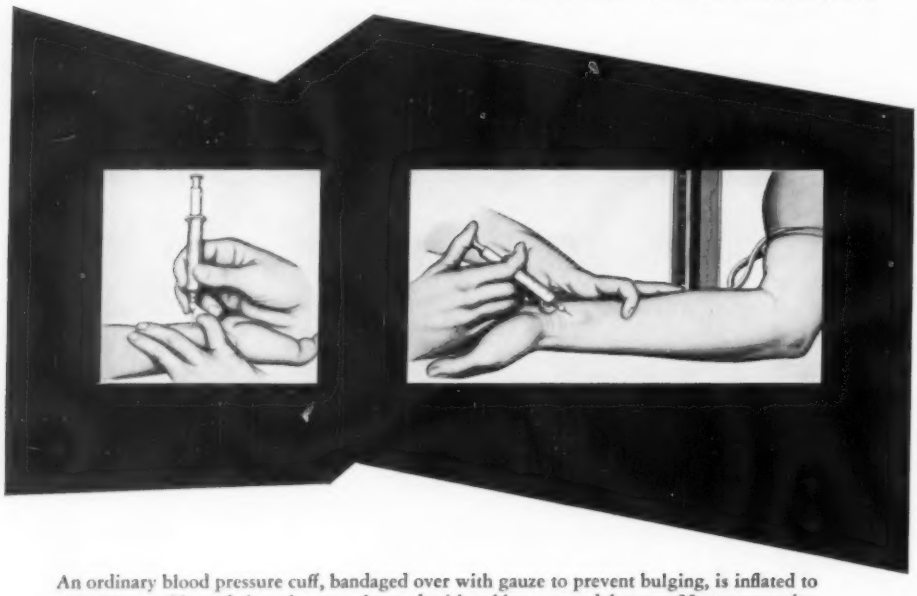

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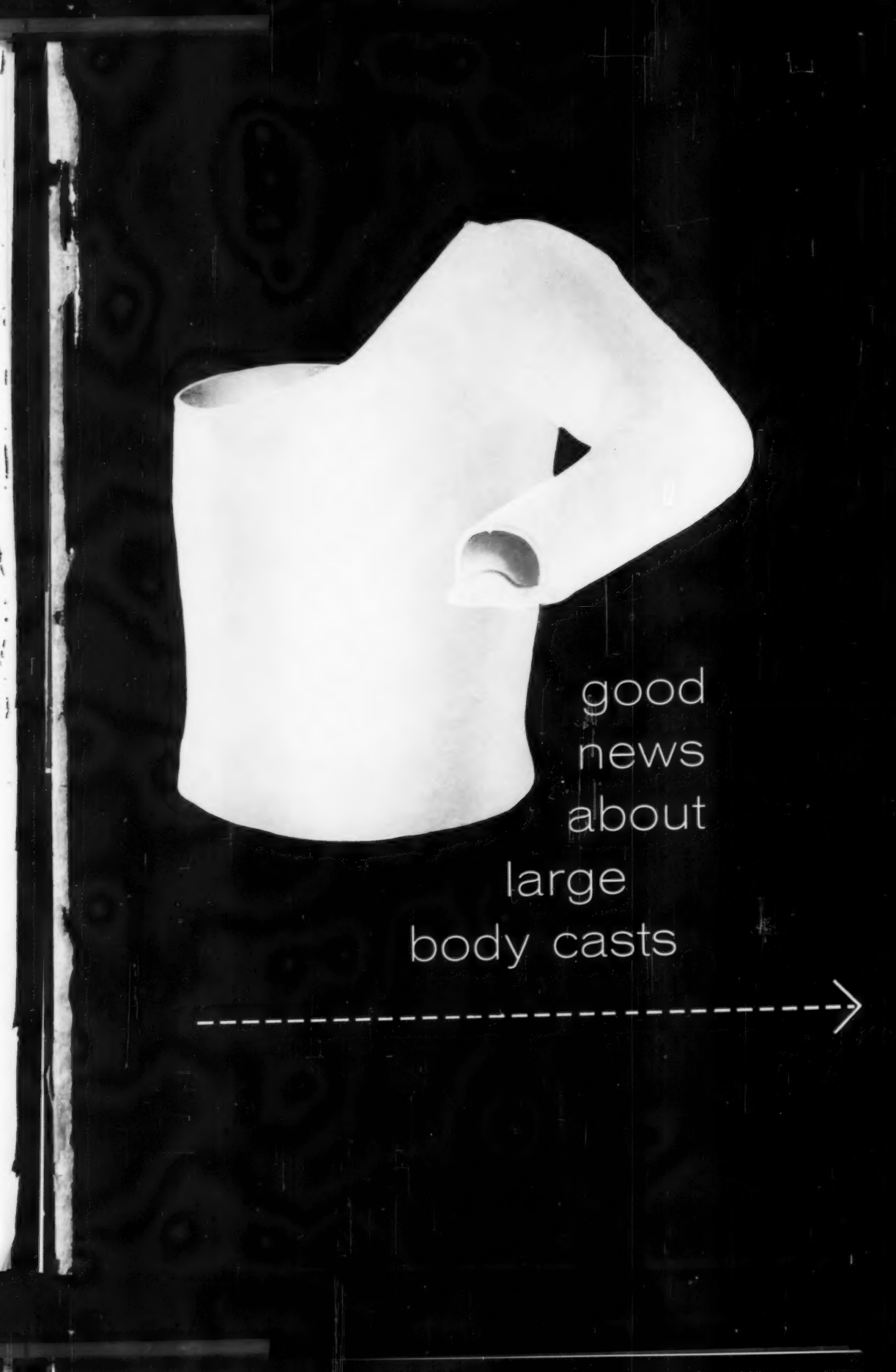
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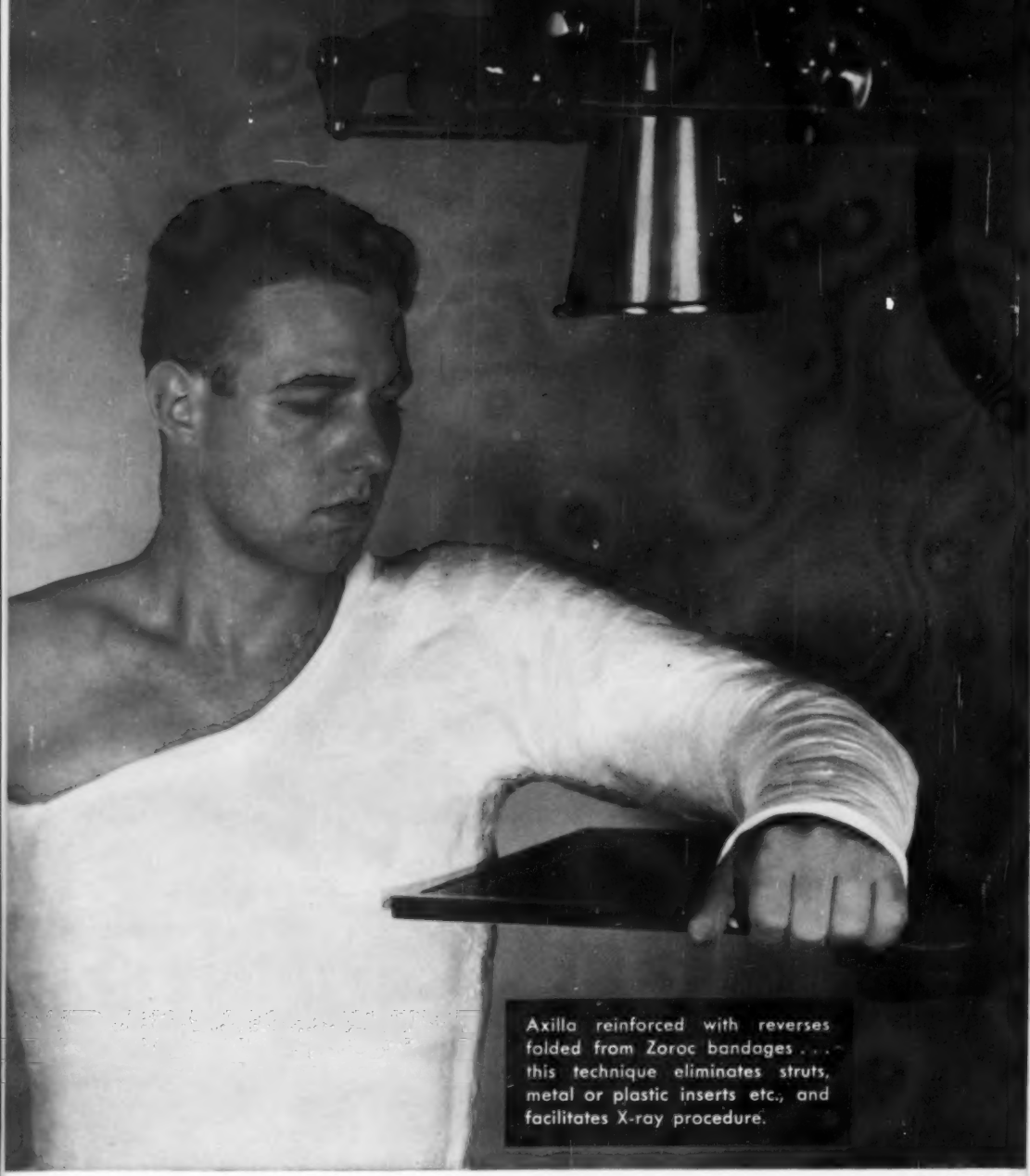

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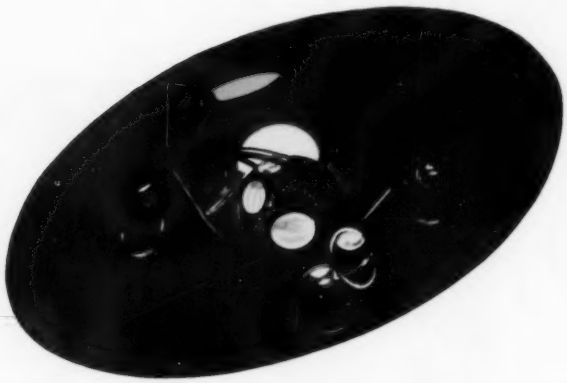

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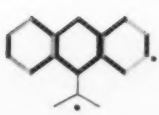

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a local anesthetic that has come so far . . . so fast*

XYLOCAINE® HCl

(Brand of lidocaine* hydrochloride)

ASTRA

Council Acceptance is your assurance of high professional standards.

for **INFILTRATION**
NERVE BLOCK
TOPICAL USE

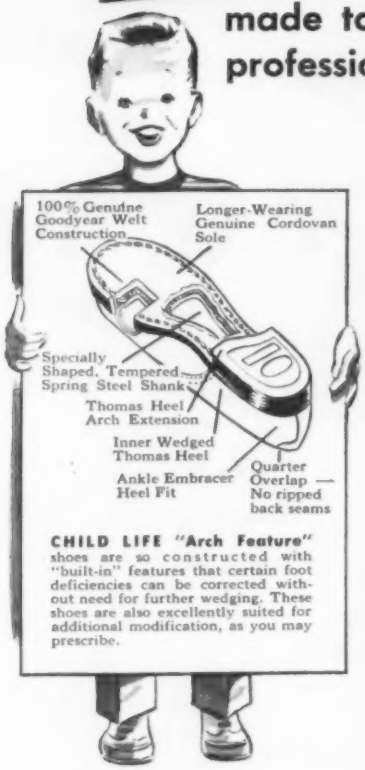
*Write for 200 reference bibliography available to physicians on request.

*U.S. Pat. No. 2,441,498

ASTRA PHARMACEUTICAL PRODUCTS, INC.
Neponset Street Worcester, Mass.

Child Life SHOES

made to merit your professional recommendation


100% Genuine Goodyear Welt Construction
Longer-Wearing Genuine Cordovan Sole
Specially Shaped, Tempered Spring Steel Shank
Thomas Heel Arch Extension
Inner Wedged Thomas Heel
Ankle Embracer Heel Fit
Quarter Overlap — No ripped back seams

CHILD LIFE "Arch Feature" shoes are so constructed with "built-in" features that certain foot deficiencies can be corrected without need for further wedging. These shoes are also excellently suited for additional modification, as you may prescribe.

A. Supple leather counter molded to embrace and support ankle

B. Broad toe area for full freedom of action

C. Ample width at the insole for the ball of the foot

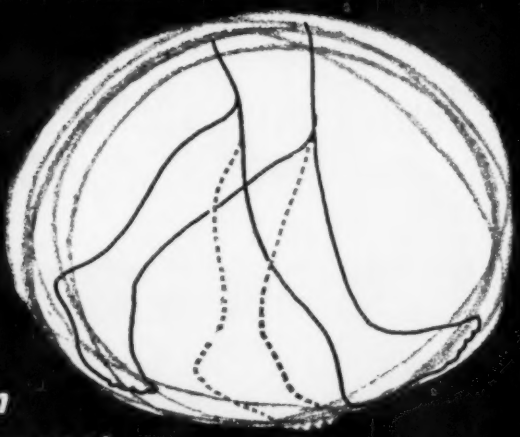
D. 100% Goodyear Welt Construction

CHILD LIFE "Regulars" are shoes you can recommend with utmost confidence when mothers ask about footwear for their children. In outline above, you see the "specification data" of CHILD LIFE lasts. These shoes also lend themselves well for your prescription work.

In almost every community from coast-to-coast, you'll find a qualified and franchised CHILD LIFE shoe dealer. These men and women have been selected for their knowledge of good fitting practices, and for their specific interest in children's footwear. You'll find them most co-operative and attentive to your prescription work. Please write for full information on CHILD LIFE shoes — on the market since 1924 — and the names of the CHILD LIFE dealers nearest you.

HERBST Shoe Manufacturing Company

Milwaukee 45, Wis.



range of motion rapidly increased

in Rheumatoid Arthritis

Sterane*

the most potent anti-arthritic

3 to 5 times more potent than hydrocortisone or cortisone

notably free of major hormonal side effects such as edema due to sodium and water retention, hypopotassemia, and hypertension

seldom requires low-sodium diets or potassium supplements in patients without cardiac complications when given in usual therapeutic dosage

preliminary findings,[1] based on the measuring of pituitary ACTH suppression potency of various corticoids, appear to indicate that STERANE is 20% more potent than the cortisone analog, prednisone

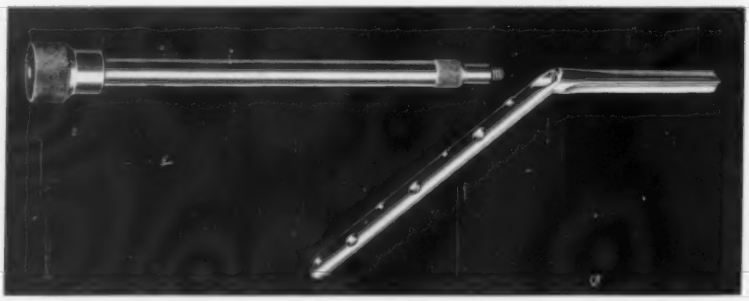
supplied: in white, scored 5 mg. tablets in the familiar Pfizer oval shape

1. Forsham, P. H., et al.: Paper presented at First Internat. Conf. on Prednisone and Prednisolone, New York, N. Y., May 31-June 1, 1955.

*brand of prednisolone

PFIZER LABORATORIES *Division, Chas. Pfizer & Co. Inc. Brooklyn 6, New York*

NEW Jewett Intertrochanteric Appliance *by Orthopedic*



A superior **one-piece forged** *plate and nail combination*

Extensive research and development led to this vastly improved style and design of Jewett nail and plate combination for fixation of trochanteric fractures. Appliance possesses great strength at apex of the angle, yet smooth design at inside juncture minimizes danger of splitting bone during insertion or pressure necrosis thereafter. Drop forged from one piece of SMo stainless steel at 135° angle. Angle may be varied as desired.

No. 273-9
Jewett One-Piece Nail and Plate Combination

No. 92--Driver
(Both Stainless Steel)

Available through surgical supply dealers

Orthopedic EQUIPMENT CO.
BOURBON, INDIANA
SPLINTS • FRACTURE EQUIPMENT • SMo INTERNAL BONE APPLIANCES • BONE INSTRUMENTS

when joints need "oiling"

Pabirin . . . safest of the antirheumatic salicylate-paba combinations

because . . . Pabirin does not produce salicylism even with heavy daily requirements. *High* blood levels are maintained with *low* salicylate dosage. It contains well-tolerated acetylsalicylic acid, the most effective of the salicylates. Pabirin is sodium- *and* potassium-free. A therapeutic amount of 300 mg. of ascorbic acid in the average daily dose of six capsules offsets depletion of vitamin C by salicylates.

And effective because . . . The synergistic effect of acetylsalicylic acid and PABA and the retarding action of PABA on salicylate excretion ensure high and sustained blood levels. Rapidly disintegrating capsules provide fast absorption and pain relief.

Pabirin is a DORSEY preparation.

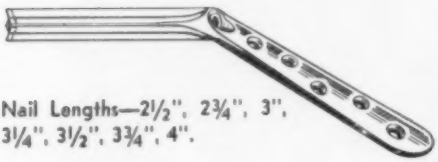
Each capsule contains:
Acetylsalicylic acid ..... 5 gr.
Para-aminobenzoic acid ..... 5 gr.
Ascorbic acid ..... 50 mg.
Average dose: 2 to 3 capsules 3 or 4 times daily.
Supplied: in bottles of 100, 500 and 1,000 capsules.

Pabirin®

Smith-Dorsey • Lincoln, Nebraska • A Division of The Wander Company

Jewett ONE-PIECE NAIL . . . AND COMPLETE SET OF INSTRUMENTS.

No. 224J—Jewett One-Piece Hip Nail. Drop forged SMO Stainless Steel—Cannulated.



Nail Lengths—2½", 2¾", 3", 3¼", 3½", 3¾", 4".

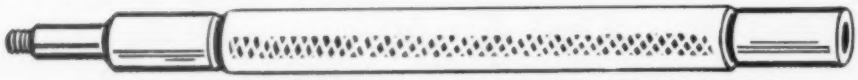
Plate Lengths—4", 5", 6".

No. 226 Guide for Jewett Hip Nail Stainless Steel

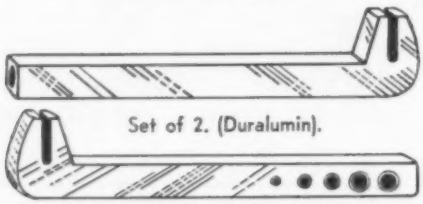
Stainless Steel Cannulated.

No. 208J Extractor-Impactor for Jewett One Piece and Smith Petersen Hip Nails.

No. W402J Henderson Cortex Reamer. Cannulated. Fits Jacobs Chuck. Stainless Steel.



No. 225 One-Piece Nail Driver. For Jewett Nails. Stainless Steel. Cannulated.



Set of 2. (Duralumin).

No. 219J Jewett Nail Plate Bending Irons.

Illustration shows one of many uses of plate bending irons.

WRIGHT MANUFACTURING COMPANY

739 JACKSON AVENUE • TELEPHONE 37-2769 • MEMPHIS 5, TENNESSEE

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less handling
ties faster
no winding–no waste

allows twice
as many ties
per suture

D & G SPIRAL WOUND

surgical gut
silk* • cotton

DAVIS & GECK INC.
A UNIT OF AMERICAN Cyanamid COMPANY
DANBURY, CONNECTICUT

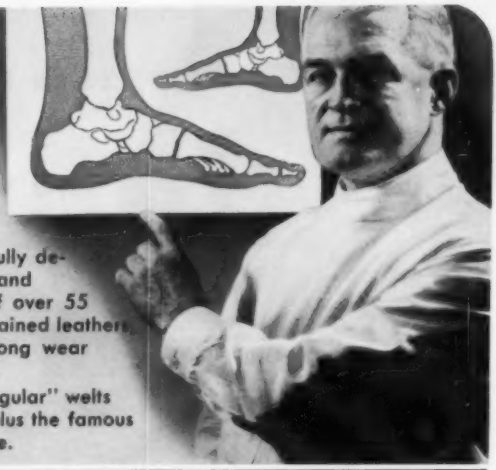
*ANACAP® BRAND

DOCTOR...

Edwards

THE SHOE FOR CHILDREN

AIDS YOUR EFFORTS



How? Edwards children's shoes are skillfully designed to meet your every prescription and recommendation. They are the result of over 55 years of craftsmanship. You'll find full-grained leathers, highest grade inner parts, proven fit, long wear and smart styling in every Edwards shoe.

A complete line—Todlins for infants, "regular" welts and cements and the "CorecTred" . . . plus the famous "Special" shoes shown here.

SUPER-PEDIC

for extreme cases of Pronation.

(Above style available in Oxfords)

PRONA-PEDIC

for extreme case of Supination.

(Above style available in Oxfords)

PIGEON-TOE

for mild cases of Supination.

(Above style available in Oxfords)

STRAIGHT-LAST

a basic shoe for corrections.

(Above style available in Oxfords)

SURGICAL BOOT

for Post - Operative fitting.

CorecTred

shoes with special fitting features.

The construction of the above Shoes maintains the longer wedge life demanded by your prescription. Recommend and prescribe Edwards.

May we send you several prescription pads and the name of your nearest Edwards retailer?

Edwards

THE SHOE FOR CHILDREN

The Shoe for Children

Philadelphia 7
Pennsylvania

*A dynamic approach to better health for the aging patient**

IN THE 40's AND 50's

"disease or body change is lurking in the background"† even though the individual may feel in good health. In this age group "Mediatric"* will help prevent premature atrophic changes due to waning sex hormone function and inadequate nutrition.

IN THE 60's AND 70's

involutional changes become increasingly apparent as the body loses its ability to resist environmental stress. "Mediatric"* will aid the aging economy cope more successfully with three important stressors: gonadal hormone imbalance, dietary insufficiency, and emotional instability.

IN THE 70's AND 80's

functional impairment is at its peak and, in most cases, is the end result of progressive disorders which had their onset in the forties. Patients treated with "Mediatric"* have responded with increased physical vigor, improved muscle tone, and better emotional balance.

†Kountz, W. B.: J.A.M.A. *153:*777 (Oct. 31) 1953.

* **"MEDIATRIC"®**

Steroid-nutritional compound

STEROIDS . . . to counteract declining sex hormone function
NUTRITIONAL SUPPLEMENTS . . . to meet the needs of the aging patient
A MILD ANTIDEPRESSANT . . . to promote a brighter mental outlook

Ayerst

Ayerst Laboratories
New York, N. Y., Montreal, Canada

Capsules, No. 252 — bottles of 30, 100, and 1,000.
Liquid, No. 910 — bottles of 16 fluidounces and 1 gallon.

5416

Average dosage, 1 capsule or 3 teaspoonfuls of liquid, daily.

In remedial exercise therapy

it takes **Both..**

COMPETENT PERSONNEL

plus the

PROPER CLINICAL TOOLS

to insure the desired end results!

The Elgin Exercise Appliance Co. has specifically designed and developed, in a scientific manner, a complete line of progressive resistance exercise equipment to meet the many and varied problems of remedial exercise therapy. This equipment gives the doctor and technician the proper clinical tools with which to administer a great variety of remedial exercises for both the surgical and non-surgical patient. It also provides a wide exercise range, from simple functional exercises to the most highly definitive focal exercises.

WRITE TODAY for available information that will give you a better introduction to this equipment and what it can do for you.

Elgin EXERCISE APPLIANCE CO.

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now!

for truly symmetrical sockets, use

CO-AXIAL SOCKET REAMERS

with the detachable shank

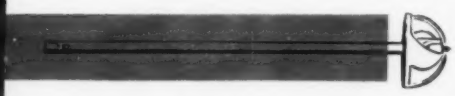
don't scrape... don't chisel... don't grind... don't try to improvise a truly symmetrical socket with instruments that *can't give you that result.*

Only

TOWER CO-AXIAL SOCKET REAMERS ARE CORRECTLY DESIGNED TO GIVE YOU:

Co-axial centering of shank • True symmetry • Precision cutting of cartilage, cortical and cancellous bone • Removal of cuttings • No clogging
All reamer sizes — 39, 41, 43, 45, 47, 49, 51, 53, 55 mm. diameter

TECHNIC—Dislocate femur and displace posteriorally. Position reaming head in acetabulum—insert shank from below (through tissue and muscles along the normal femoral-neckline) and engage reaming head. After reaming is complete draw out shank and remove reaming head which retains cuttings.



Since the reamer heads are available in a large range of sizes, please specify reamer diameter or mention the sizes of **cups** *or* **prostheses** *with which they are to be used.*

SPECIAL GROUP PRICE
Any three reaming heads, plus detachable shank, plus brace—$175.00 complete.

THE TOWER COMPANY, INC.

P. O. Box 3181, Seattle 14, Washington

Fifth and Stevens, Geneva, Illinois

CAMP SUPPORTS and APPLIANCES *for many needs*

CAMP HEAD HALTER APPARATUS
A comfortable head halter made of strong cream colored canvas lined with thick fleeced flannel. Complete with overhead pulley and spreader bar for easy home use.

CAMP LEWIN COTTON COLLAR
This simple, comfortable, effective cotton collar exerts a protective, resilient, compressive and distractive force. It helps retain body heat and reminds your patient to be careful.

CAMP RIB BELTS
Exclusive "Contour cut" provides snug fit and uniform support on the full width of the belt. Made for comfort out of foam rubber vulcanized on tackle twill and lined with fleeced flannel.

CAMP SUPPORTS IMMEDIATELY AVAILABLE THROUGH AUTHORIZED CAMP DEALERS

S. H. CAMP and COMPANY, Jackson, Mich.
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OFFICES: 200 Madison Ave., New York; Merchandise Mart, Chicago
FACTORIES: Windsor, Ontario; London, England

Adrenosem®

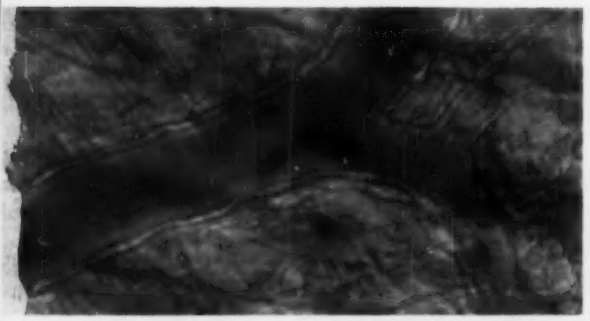
SALICYLATE

(Brand of carbazochrome salicylate)

Adrenosem checks bleeding by decreasing capillary permeability and promoting retraction of severed capillary ends. It aids in maintaining capillary integrity by direct action on the capillary walls.

Adrenosem does not alter blood components, nor does it affect blood pressure or cardiac rate. No toxic reactions have been reported in more than two years of clinical use.

Trauma from snake venom produces hemoconcentration and stasis, indicative of altered vascular permeability.



Trauma does not produce petechiae following Adrenosem injection.

VISUAL PROOF OF ADRENOSEM'S EFFECTIVENESS

To confirm the action of Adrenosem, the cheek pouch of a hamster was irritated with snake venom, which has the property of making the capillaries more permeable. A great many petechiae appeared on the surface and a 500X magnification showed the capillaries with extravasation of erythrocytes. Another animal was treated with Adrenosem, and 30 minutes later, the same amount of snake venom was used to irritate the cheek pouch. Microphotographs show the capillary walls intact and the blood cells coursing through the capillaries, without signs of escaping erythrocytes.

SUPPLY

Ampuls, 5 mg., 1 cc.: packages of 5.

Tablets, 1 mg. (s.c. orange): bottles of 50.

Tablets, 2.5 mg. (s.c. yellow): bottles of 50.

Syrup, 2.5 mg. to each 5 cc. (1 teaspoonful): 4 oz. bottles

REFERENCES

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2. Fulton, M. D., Department of Biology, Boston University. To be published.
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8. Green, D. P., and Richter, D.: Adrenaline and Adrenochrome, Biochem. J. 31:625-634, 1937.

THE S. E. MASSENGILL COMPANY

BRISTOL, TENNESSEE • NEW YORK • KANSAS CITY • SAN FRANCISCO

Welling up of blood upon incision of lid and conjunctiva, coming in ophthalmic procedures, hampers surgery.

Minimal bleeding after Adrenosem therapy facilitates surgery and promotes healing.

Mastoidectomy with a bloody field obscures view, requires frequent suctioning.

After Adrenosem therapy. Note clearer operative field with minimized bleeding.

Detailed literature on request

Adrenosem®

SALICYLATE

(Brand of carbazochrome salicylate)

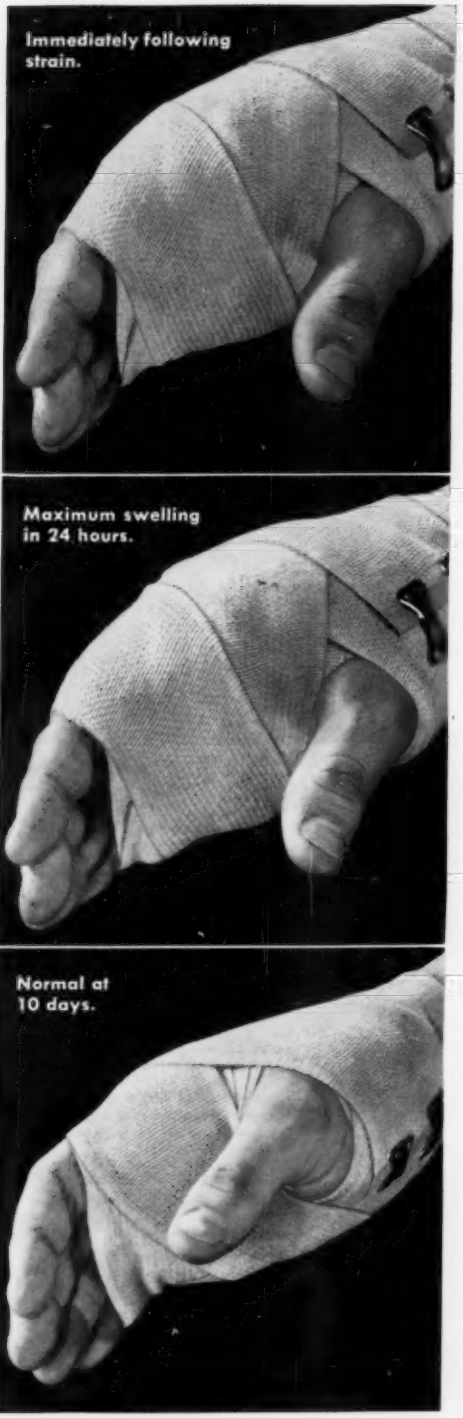
DOSAGE

- preoperatively to control oozing during surgery and provide clearer operative field: one to two ampuls (5 to 10 mg.) every two hours prior to surgery for two doses.
- postoperatively to prevent hemorrhage and check oozing: one to two ampuls (5 to 10 mg.) every two hours until there is no indication of undue bleeding. To maintain control, one ampul may be administered every three hours or 1 to 5 mg. orally t.i.d.
- to control active bleeding: one ampul (5 mg.) every two hours until bleeding is controlled; frequency of dose may then be diminished.
- to control mild, low-grade bleeding: one ampul (5 mg.) every three or four hours until bleeding is controlled; then 1 to 5 mg. orally four to five times daily until bleeding ceases.
- maintenance dosage to prevent bleeding in conditions where small vessel integrity may be impaired: 1 to 5 mg. orally t.i.d.; if bleeding ensues, dosage may be increased 1 to 5 mg. orally every three or four hours; if bleeding persists, oral dosage should be supplemented with one ampul (5 mg.) daily.
- pediatric dosage: up to four years of age—) mg. intramuscularly or orally with same frequency as for adults, until bleeding is controlled. From four to twelve years of age—one-half the adult dosage as indicated.

THE S. E. MASSENGILL COMPANY

BRISTOL, TENNESSEE • NEW YORK • KANSAS CITY • SAN FRANCISCO

New TENSOR adjusts itself to the swelling



Maintains proper support without constriction throughout every stage of swelling

Here's an elastic bandage that is able to give and take with the swelling.

Tensor elastic bandage is made with *live rubber threads*. Unlike bandages made with ordinary rubber, Tensor never constricts. Never binds. Gives perfect, even support during every stage of swelling.

And with *Tensor*, Doctor, you can bandage for low pressures as easily as higher pressures. Tensor elastic bandage holds whatever pressure *you* apply.

Heat won't affect its elasticity, either. Tensor elastic bandage can be washed and dried in automatic machines—time after time—without losing its "snap".

Shouldn't your patients have the advantages of new Tensor elastic bandage?

NEW! PLASTIC ENDS eliminate bulky pressure points — easier, safer to apply.

New TENSOR®
ELASTIC BANDAGE

Woven with Heat-Resistant *live rubber* threads

BAUER & BLACK

Division of The Kendall Company

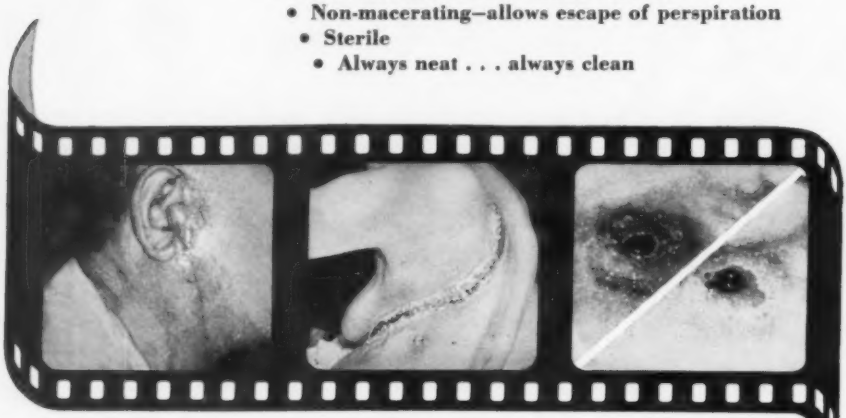
SPECIAL FOR DOCTORS
Save 32% when you order in bulk

The modern approach to wound dressing
in Hospital, Office or Industrial Clinic

AEROPLAST® PLASTIC SPRAY-ON DRESSING

BRAND OF VIBESATE[1]

- **Non-adherent—to raw wound surfaces**
- **Non-macerating—allows escape of perspiration**
- **Sterile**
- **Always neat . . . always clean**



AS A BANDAGE*

Laceration (shown above)
Film dressing conforms to hard-to-bandage sites
Scalp wounds
Abrasions and Burns
Skin eruptions

*If hemostasis is complete, use Aeroplast alone. If incomplete, apply one coat of Aeroplast, a layer of gauze, then spray gauze and surrounding skin area with Aeroplast.

AS A SURGICAL DRESSING

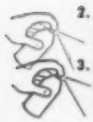
Thoracotomy (shown above)
Appendectomy
Herniorrhaphy
Major burns
Vein ligations
Mastectomy
Decubitus ulcers

AS A PROTECTIVE COATING

Excoriation (shown above)
Area around ileostomy cleared in 24 hours.
To prevent excoriation
To control dermatologic distress, e.g., itching or burning as in sunburn or poison ivy.
Under skintight casts
Episiotomy

easy to apply

1. Spray a light film onto aseptic dry wound from a distance of 6 to 12 in. Cover adjacent area of intact skin to provide anchorage. Hemostasis should be complete. May be applied over sutures.



2. Allow film to dry for 30 seconds. (sufficient time for the acetone solvent to evaporate)

3. Repeat "spray and let dry" procedure (steps 1 and 2 above) two more times.

Supplied in 6 oz. aerosol-type dispenser.

Available through your surgical supply dealer or prescription pharmacy.

Want literature?

Write AEROPLAST CORPORATION
422 Dellrose Avenue, Dayton 3, Ohio

1. Vibesate (Aeroplast) — New and Nonofficial Remedies, 1955, p. 541.

Prosthetic Improvements through Constant RESEARCH

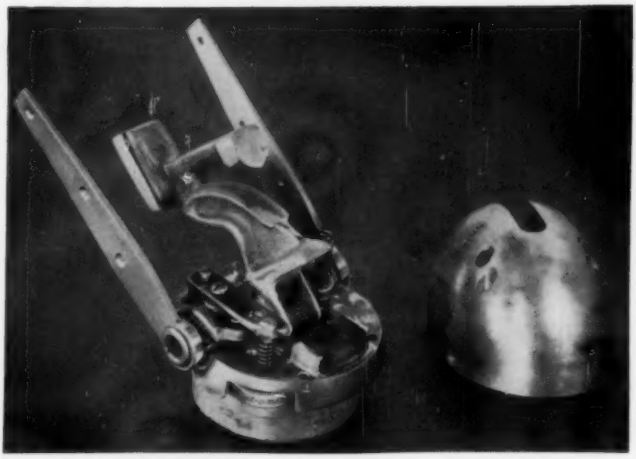
HANGER Posthesis and Prosthetic Methods have been constantly improved over the years through RESEARCH. This research includes cooperation with the National Research Council under the auspices of the National Academy of Sciences. HANGER, in addition, maintains a continuing research program of its own.

As a result of this continuing effort, HANGER is developing and testing new ideas, new methods, and new materials. From these activities have come many outstanding achievements, adding greatly to the comfort and ever-increasing utility of Prosthetic Appliances. Some of these are shown on this page.

This program is cooperatively carried on by the many HANGER Companies in key cities throughout the United States. The results are available to you through any HANGER office. These efforts continue today, and will in the future—studying, planning, and developing new improvements to produce an ever-better Prosthesis.

The UCLA Course

Certified Prosthetists from the various HANGER offices have been sent to the University of California in Los Angeles to attend the Special Course on Upper-Extremity Prosthetics. This course, utilizing many of the most recent findings of engineering and prosthetics research, is designed as advanced training for men already actively engaged in rehabilitating amputees. This is but another step in the traditional HANGER policy of ensuring that our Clients receive the best Prosthetic Service possible. HANGER Clients thus benefit from the most-up-to-date engineering and prosthetics research.



The "Adapt-O-matic" Knee

This new Knee embodies important features: Finger Tip Control of friction adjustment, Remote Control regulating swing-phase action, Self-Lubrication, Adaptability for any limb. This Knee solves the problem of change in knee action due to climatic or temperature variations—adjustment can be made inconspicuously through the clothes in a matter of moments. In addition, the Remote Control gives the wearer definite control of the limb, resulting in greater confidence and ability to swing the limb comparable to a natural leg.

CINEPLASTY

Studies on muscle physiology in the cineplastic muscle motor have been conducted at the Army Prosthetics Research Laboratory and Navy Medical Centers, HANGER has been extremely interested in cineplastic developments, and has furnished a number of Prosthesis in connection with this research. As a result, HANGER has developed the "Cinematic" Arm, designed for application to patients with cineplasty operations.

Hanger PROSTHETICS #26

AVAILABLE AT AUTHORIZED FACILITIES IN THE FOLLOWING CITIES:

ATLANTA 1, GA.
BALTIMORE 1, MD.
BIRMINGHAM 1, ALA.
BOSTON 16, MASS.
CHARLESTON 2, W. VA.
CHARLOTTE 2, N. C.
CHICAGO 5, ILL.
CINCINNATI 2, OHIO
COLUMBIA 5, S. C.
COLUMBUS 8, OHIO
DALLAS 1, TEXAS
EVANSVILLE, IND.
INDIANAPOLIS 2, IND.
JACKSONVILLE, FLA.
KNOXVILLE, TENN.
MEMPHIS, TENN.
MIAMI 37, FLA.
MOBILE, ALA.
MONTGOMERY, ALA.
NASHVILLE, TENN.
NEW ORLEANS 19, LA.
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OKLAHOMA CITY 3, OKLA.
ORLANDO, FLA.
PHILADELPHIA 7, PA.
PITTSBURGH 30, PA.
RALEIGH, N. C.
RICHMOND 18, VA.
ROANOKE 12, VA.
ST. LOUIS 3, MO.
SHREVEPORT, LA.
TAMPA 2, FLA.
WASHINGTON 13, D. C.
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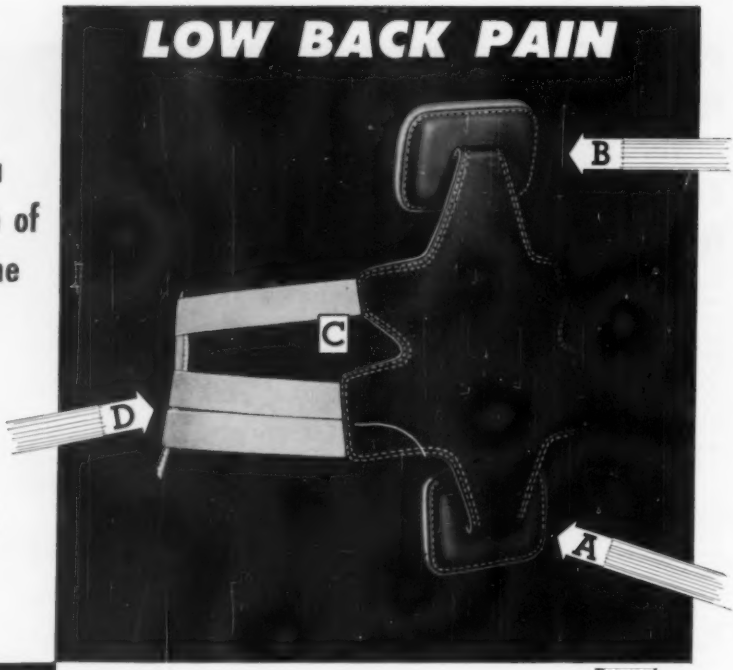
LOW BACK PAIN

Announcing a New Principle of Relief with the Bell Posture Bridge by TRUFORM



Patented

As with all Truform Anatomical Supports, this Bell Posture Bridge is

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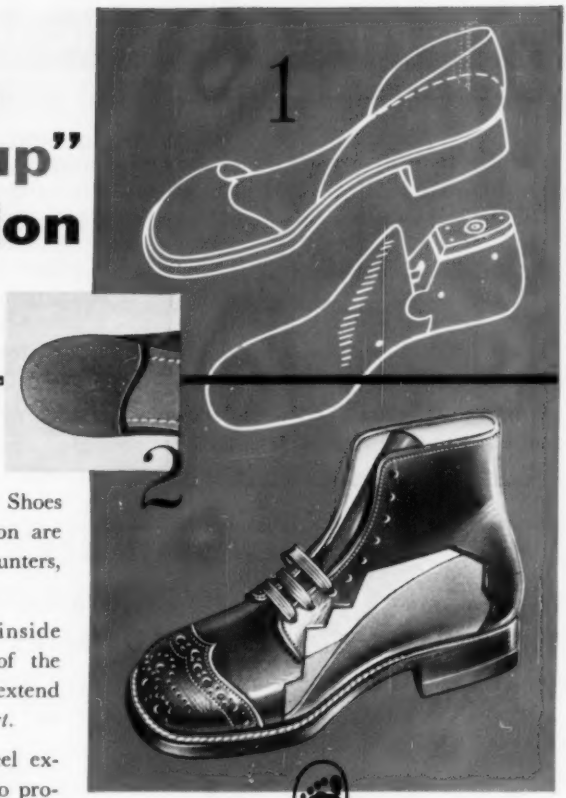

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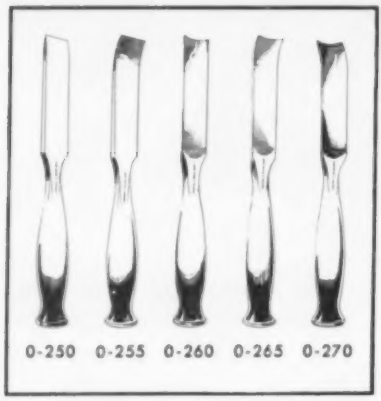

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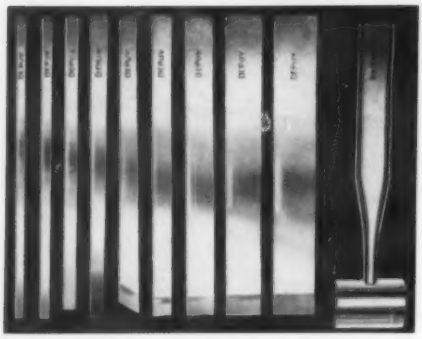

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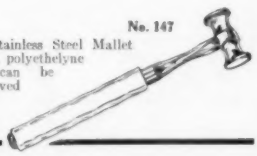

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VOL. 37-A, NO. 5 OCTOBER 1955

The Journal of
Bone and Joint Surgery
American Volume

COMPLETE MUSCLE TRANSPOSITION *

BY E. R. SCHOTTSTAEDT, M.D., LOREN J. LARSEN, M.D.,
AND FREDERIC C. BOST, M.D., SAN FRANCISCO, CALIFORNIA

From the Department of Orthopaedic Surgery, University of California School of Medicine, and the Shriners' Hospital for Crippled Children, San Francisco

Most muscle transplantations in use at present shift the insertion of a muscle to accomplish a new or additional function. This paper introduces a variation of one established muscle transplantation and suggests several applications of the same principle to other muscles. In all, twelve cases of muscle transposition are reported.

The literature has been extensively reviewed, to determine what has been written on both muscle and tendon transplantation. Except for transplantation of the pectoralis major to the elbow, originally described by Clark in 1946, a search of the literature revealed no previous mention of the procedures we are about to describe.

The procedures herein detailed are based on the concept that a muscle may be freed at both its origin and its insertion during the same procedure, and may be shifted to a new location where it will function successfully, provided that its nerve and blood supply remain intact. Such procedures may be used in reinforcing or replacing muscle function lost by paralysis, absence of muscles, or congenital abnormalities.

MUSCLE TRANSPOSITION TO REINFORCE OR REPLACE ELBOW FLEXION

In 1948, our attention was first called to the work of Clark, who described the transplantation of the lower two thirds of the pectoralis major to be used as a flexor of the elbow.

The technique employed uses the chondrosternal two thirds of the pectoralis major. In many mammals, there is a separate lower portion of the pectoralis major, known as the pectoralis externus, which is attached to the fourth, fifth, and sixth ribs. The corresponding part in man is fused to the main muscle, but still retains its separate nerve and blood supply.

This technique was first used at Shriners' Hospital, San Francisco, on a boy with Erb's palsy who could not completely flex his elbow. He was eight and a half years old. Before surgery, he was able to lift only through a range of 90 degrees and could handle a weight of only one-half pound. The first procedure was done on April 26, 1948; the second on June 28 of the same year. The chondrosternal two thirds of the pectoralis major was used. The nerve supply and blood supply of this portion of the muscle were carefully preserved and the muscle was detached at both its origin and its insertion. It was then transposed so that its origin, after being transferred through a subcutaneous tunnel, came to lie over the surface of the biceps belly and the tendinous biceps insertion

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27, 1954.

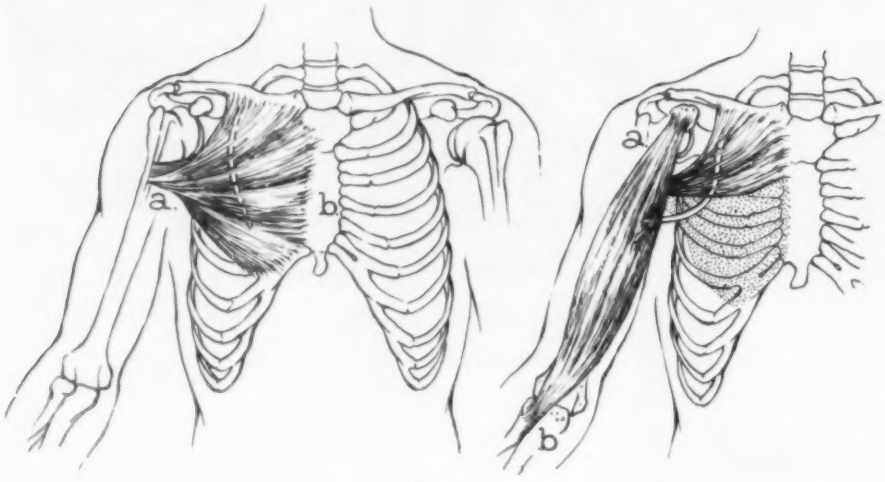

FIG. 1

Showing the lower two thirds of the pectoralis major transposed to extend from the coracoid process of the scapula to the radial tubercle, reinforcing or replacing elbow flexion. *a*, insertion; *b*, origin.

so that it could easily be sewed to both as desired. In the original procedure described by Clark, the insertion of the pectoralis major was not transferred.

However, in the initial procedure done in this series, it was decided to shift the humeral insertion to the coracoid process, as well as to transplant the origin to the biceps tendon of insertion (Fig. 1). This seemed to maintain the fiber length of the muscle more satisfactorily and to give a better functional muscle-fiber unit.

The postoperative result was at first disappointing and on June 28, 1948, reoperation was performed. At this time, the coracoid attachment was again visualized and the previous insertion was taken up approximately one and a half inches (four centimeters). After operation the arm was held at 90 degrees for six weeks. After the muscle shortening, marked improvement was shown.

When last seen, this boy could lift a three-pound weight through a full range of flexion and, by resorting to trick motions, could lift a five-pound weight.

The length of postoperative immobilization is optional and can certainly be decreased by a carefully supervised postoperative program. There is no reason that activity through a limited range cannot be allowed as early as two or three weeks postoperatively.

The same procedure has been followed with four other patients, on two of whom bilateral transpositions were done.

F. W., a boy of six, was operated on in June 1952, because of bilateral congenital absence of the elbow flexors. Elbow flexion was possible passively to only 90 degrees (Figs. 2-A and 2-B). The boy had associated shoulder abnormalities, indirectly related to our present problem. There was no vestige of fascia or muscle to which the muscle could be sutured. Therefore the attachment was made through a drill hole in the ulna and to the distal anterior capsular surface of the elbow. After operation he improved until he could lift both hands to his mouth. The left had greater range than the right, but he could flex either to 90 degrees (Fig. 2-C).

C. Y., aged twelve, was operated on for poliomyelitic paralysis of the elbow flexors. This boy had little associated involvement and obtained the best result. He can lift a weight of five pounds through a complete range and can hold eight pounds at 90 degrees.

An adult female, C. B., aged thirty, was operated on in May 1952, for poliomyelitic involvement of her right elbow flexors. Her poliomyelitis had occurred ten years before. Her first comment after operation was that she had regained supination and that, if she had obtained no other improvement, the procedure would still have been worth-while. Her flexion power was also appreciably improved. Unfortunately, we lost contact with her six months later.

FIG. 2-A

FIG. 2-B

Fig. 2-A: F. W. Showing method of bringing hand to mouth with the knee as support, before operation.

Fig. 2-B: Showing method of bringing hand to mouth by gravity, before operation.

Fig. 2-C: Showing the left arm actively flexed to 90 degrees against gravity after transposition of the pectoralis major.

FIG. 2-C

E. B., disabled due to arthrogryposis, had strong elbow extension, but no active elbow flexion. Her passive range of flexion was from 180 degrees to 90 degrees. There were many associated deformities and weaknesses. In August 1951, the left pectoralis major was transplanted to provide elbow flexion. A strip of rectus abdominis sheath was also taken to provide more muscle length.

In January 1953, the same procedure was followed on the right elbow and a revision of the left was done in February of the same year. This revision consisted in section of the elbow capsule posteriorly and in tightening of the transposed muscle by taking up extra length at the coracoid process. She could then flex the left elbow from 120 to 100 degrees and the right from 160 to 90 degrees. It is to be remembered that in this patient the pectoralis major muscles were poor both in excursion and in strength. The results of the operations, although not brilliant, were gratifying to the patient, who had marked functional improvement and greater ease in feeding herself.

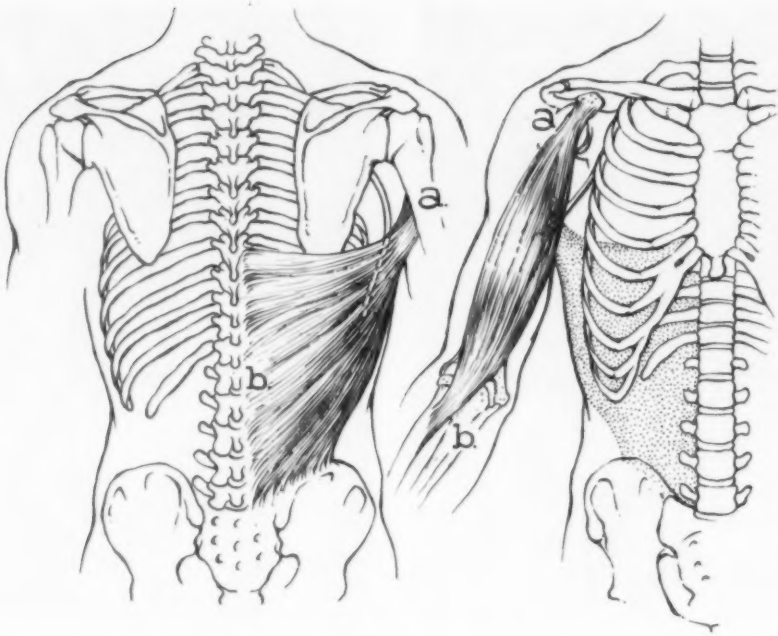

FIG. 3

Latissimus dorsi transposed to extend from the coracoid process of the scapula to the radial tubercle, reinforcing or replacing elbow flexion. *a*, insertion; *b*, origin.

From the success of these procedures, it appeared obvious that there were other possibilities of applying the principle of free muscle transposition. The essentials for success are, of course, a sufficiently strong muscle with a long neurovascular pedicle, so that the muscle can be shifted freely to a new location. As we were looking for other possibilities, it became apparent that the latissimus dorsi is an ideal muscle. It has a satisfactory pedicle and its fiber length and anatomical length are equivalent to those of the pectoralis major.

On April 22, 1953, C. R. G., aged twelve and a half, was admitted to Shriners' Hospital. He had contracted paralytic poliomyelitis eight months before admission. A suitable program of physical and occupational therapy had been carried out at another hospital in an attempt to rebuild his elbow flexor power, but without success.

On examination, he presented a weak shoulder, weak hand, and very weak left elbow. The left elbow flexors could lift approximately one half pound, but no more. It was felt that he would be a suitable candidate for elbow flexorplasty, since it was unlikely that much more power would be gained after this length of time without prolonged heavy-work therapy. The latissimus dorsi was found to be an excellent muscle. It was carefully freed from its iliac and spinal origin. In freeing it proximally, care was taken not to slip under the serratus anterior or damage the nerve and blood supply. The insertion was then detached and a tunnel was made, so that the latissimus dorsi could be passed, origin first, to lie forward beneath the pectoralis major tendon. Its origin was sutured to the biceps tendon at the elbow and to the lower biceps muscle. The insertion easily reached to the coracoid process (Fig. 3).

Approximately two weeks after the elbow flexorplasty, a wrist arthrodesis was done. While being anaesthetized for this, the boy went through a period of induction confusion during which he demonstrated good power in his elbow transplant. It was feared then that the transplant had pulled loose. However, this was later proved to be untrue. At six weeks, the long-arm cast was changed to a short-arm cast. Very soon thereafter, he began to lift the weight of his arm and cast plus one pound. The strength continued to improve until he could lift three pounds readily and four pounds from a starting position of 90 degrees.

It is realized that probably some improvement would have occurred if he had con-

FIG. 4-A

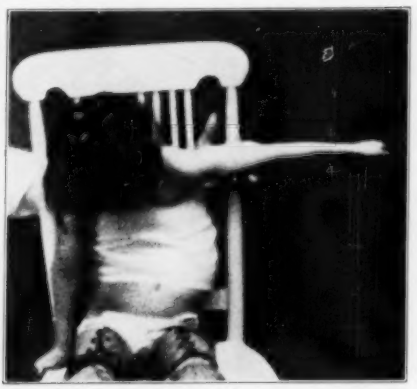

FIG. 4-B

Fig. 4-A: T. L. D. Showing attempted elbow extension before surgical treatment.
Fig. 4-B: Full elbow extension was possible after transposition of the latissimus dorsi.

tinued with the intensive physical and occupational therapy carried out postoperatively. However, we feel certain that the greater portion of his increased strength is the result of added normal muscle volume. Elbow flexors do not increase their strength as rapidly as this when they have reached a plateau following several months of previous therapy.

In October 1953, another latissimus dorsi transplantation was done in a different hospital.

P. A., aged twelve years, had had a Steindler flexorplasty done three years before. However, she was unable to bring her hand to her mouth and had lost supination. At three weeks, the transplanted muscle could be felt to contract strongly as the elbow was flexed from a position of 90 degrees of flexion gained passively. She was not allowed to extend further at this time in order to avoid stress on the suture line. At six weeks, her elbow stability was increased and she had regained supination.

It is to be noted that the transplantation of the latissimus dorsi is not an innocuous procedure. Care must be taken that the latissimus dorsi is not doing a necessary job in its original location. For instance, it has often been observed that it may be the only lateral trunk muscle capable of elevating the pelvis for a forward step. If this is the case, the muscle should not be moved under any circumstances. Transposition of this muscle may produce or influence a scoliosis. Care must be taken to see that the latissimus dorsi is not an important factor in the balance of the lumbar portion of the spine in children at an age when structural scoliosis may easily develop.

Two unsuccessful procedures to gain elbow flexion were attempted. They are reported here because they illustrate the method of approach to the problem.

The first was the use of a long strip of fascia lata from the inferior third of the vertebral border of the scapula. This was routed from the inferior third of the vertebral border of the right scapula across the mid-line subcutaneously. Thence it went beneath the left scapula between the serratus anterior and the subscapularis to become superficial at the left coracoid process. There it was directed over the tendon of the pectoralis minor and thence to the left biceps tendon at the radial tubercle. This first pulled out at the scapula and, on later revision, the fascia became necrotic and had to be removed.

The second procedure was done by leaving the left latissimus dorsi attached to the humerus and by detaching its origin. The origin was then redirected so that the muscle lay over the right shoulder (subcutaneously) and ended four inches (10 centimeters) from the right radial tubercle. It was extended to the tubercle by fascia. Infection caused many adhesions and, although it now functions as a scapular rotator, it is too adherent to flex the elbow joint. This attempt shows some promise but the details have not yet been completely worked out.

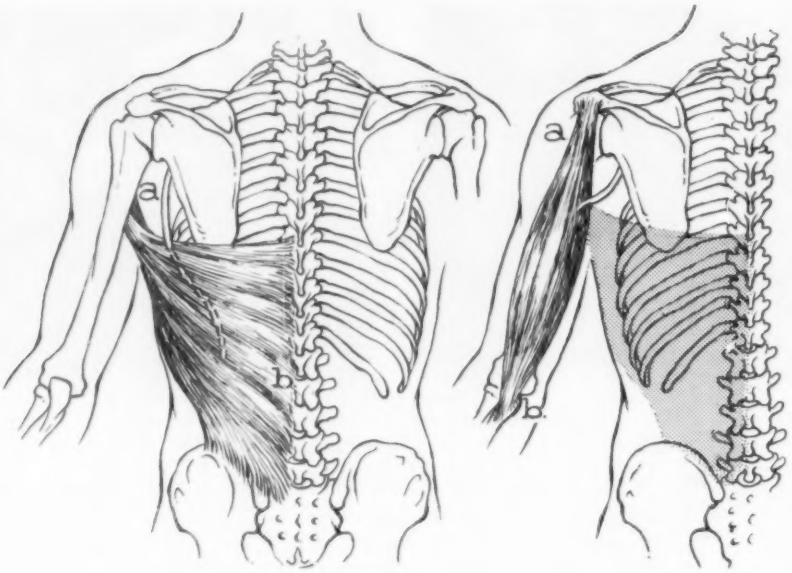

FIG. 5

Latissimus dorsi transposed to extend from the acromion to the olecranon, reinforcing or replacing elbow extension. *a*, insertion; *b*, origin.

The suggestion of using power from the opposite side of the body is not a new one. Haas reported an excellent transplantation of the external oblique muscle to stabilize pelvic obliquity due to cerebral palsy. Long before that, Fritz Lange had conceived a latissimus dorsi transplant to aid the opposite hip in extension and abduction.

Several techniques have been described in the past to provide or reinforce elbow flexion. The most successful is Steindler's flexorplasty with transplantation of the finger and wrist flexor origins proximally on the humeral shaft. Frequently the addition of a bone block to hold the elbow in flexion reinforces the gains from flexorplasty. Even if the resultant improvement is slight, it still helps to maintain the elbow in good working position for the transplant.

Bunnell suggested a useful modification of this procedure and described a method for transplantation of the triceps. So far as we know, he was also the only one to suggest the use of the sternocleidomastoid as an elbow flexor.

In 1910, Bradford reported three cases in which he had used the pectoralis minor to reinforce elbow flexion. He detached it from the chest wall and placed it as far down the biceps as possible, leaving its coracoid insertion intact. This allowed the patient barely to lift against gravity, but did not provide adequate power.

Pipkin detailed no cases, but suggested detaching the teres major or subscapularis from their insertion after shoulder arthrodesis and carrying the insertion as far as possible down into the biceps before reinsertion to this muscle. We have never seen this procedure done, but would think it probably somewhat ineffective. The tendon is too short to reach beyond the stretched and weakened muscle of the biceps to its tendon of insertion.

MUSCLE TRANSPOSITION TO REINFORCE OR REPLACE ELBOW EXTENSION

Elbow extension is seldom seriously missed, since gravity can be made to take its place, except in overhead activities or in crutch-walking. Of course, there are many other heavy activities in which elbow extension is essential, but these are seldom the concern

of the paralytic. While extension of the elbow cannot be reinforced with great power by any known technique, it can be materially improved to aid in crutch-walking. This is demonstrated by the following case:

T. L. D., aged five years, was admitted to Shriners' Hospital in January 1952. She had had paralytic poliomyelitis in 1949 and was unable to walk. Her left biceps was good, but triceps power was trace to zero (Fig. 4-A). It was felt that additional triceps strength would be most useful. On February 18, 1952, the latissimus dorsi was mobilized. Both the insertion and the origin were freed, so that the origin could be sutured to the lower triceps and olecranon and the insertion could be transplanted to the acromion (Fig. 5).

The power of the muscle proposed for transposition was excellent. Before surgery, the child had been unable to lift the hand and forearm in extension against gravity. After operation, the power of the transplant rapidly improved, so that the elbow could be brought to full extension against gravity.

Crossed abdominal fascial transplants were applied and, after suitable bracing and training, the child was able to walk. It seemed that the improved strength in the elbow extensor was of actual value in helping her to handle crutches.

We know of no other successful transplantation to improve elbow extension except that of rolling back the brachioradialis as described by Ober and Barr, but we feel sure that, since the latissimus dorsi can be used both as an elbow flexor and an elbow extensor, the pectoralis major would be no less versatile. It would probably give the same degree of success as the latissimus dorsi and could easily be made to reach anatomically. Transplantation of this muscle would not be technically difficult.

FIG. 6-A

ALLIED PROCEDURES

Several partially successful procedures were done on the shoulder, which need not be detailed. However, transplantation of the origin of the sternocleidomastoid laterally to the acromion process was sufficiently successful to merit attention.

FIG. 6-B

FIG. 6-C

Fig. 6-A: E. T. Showing attempted elevation of the right scapula before operation.

Figs. 6-B and 6-C: Anterior and posterior views showing outline of course of the transposed sternocleidomastoid as it lifts the scapula.

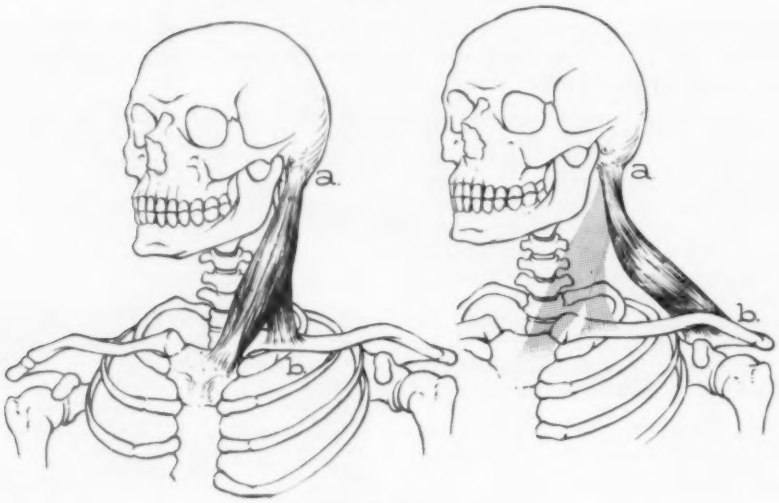

FIG. 7

Sternocleidomastoid origin transplanted to the acromion, reinforcing scapular rotation. *a*, insertion; *b*, origin

A Chinese boy, E. T., aged thirteen, was admitted to Shriners' Hospital in January 1953. He had involvement of his right upper extremity (Fig. 6-A) from old paralytic poliomyelitis. After his hand function had been improved by wrist arthrodesis and tendon transplantation, it was decided that shoulder arthrodesis would be valuable. However, because of weakness in the shoulder elevators and in the serratus anterior, this was not deemed feasible. After careful study, it was decided that the sternocleidomastoid could be used as a shoulder elevator. Although it was appreciated that it might not be cosmetically pleasing, if left attached to its normal insertion at the mastoid process, it was thought that it should have good power from this position. If desired, the insertion could always be moved at a later date to the superior nuchal line and the upper cervical vertebrae.

Therefore, the sternocleidomastoid was detached from the clavicle anteriorly and was extricated from the cutaneous nerves. It was then redirected subcutaneously and was attached to the acromion at the point of insertion of the outermost fibers of the trapezius (Fig. 7). The muscle worked well in its new location from the outset and provided good shoulder elevation augmenting the levator anguli scapulae and the upper trapezius fibers.

To give better scapular control, a fascial transplant from the scapula to the chest wall was done, as described by Dr. C. L. Lowman. This seemed to improve the power of the transplanted sternocleidomastoid. As a result the boy had much more control of his shoulder girdle than he had had before the combined surgical procedure. Each step resulted in improvement: the first in shoulder elevation, the second in forward shoulder placement. Other transplantations of active muscles could not be done in this case since no suitable muscle was available.

MUSCLE TRANSPOSITION TO IMPROVE BALANCE, FLEXION, AND ROTATION IN THE CERVICAL PORTION OF THE SPINE

In December 1951, E. S. was entered in Shriners' Hospital in San Francisco. He had had paralytic poliomyelitis in 1947 and had recovered well, except for residual paralysis affecting chiefly his sternocleidomastoid and scaleni bilaterally. He was unable to balance his head properly and constantly walked with his right shoulder elevated and his head propped against the right shoulder to prevent it from falling posteriorly. He could not raise his head against gravity when lying supine without the help of his hands. He was

unable to play actively with children of his own age, since he had very poor control of his head position. There was an accentuation of his cervical curve because of some neck-extensor weakness. However, his major difficulty was related to the loss of the scaleni and of the sternocleidomastoids.

Operation was performed on the right anterior cervical region on January 7, 1952, and on the left side on January 21, 1952.

In this procedure, the major portion of the pectoralis major was detached from its origin and from its insertion on the right side. Great care was exercised to preserve the blood and nerve supply. On the left side, only the lower two thirds was transposed.

FIG. 8-A

FIG. 8-B

Figs. 8-A and 8-B: E. S. Showing the right and left pectoralis major muscles after transposition and demonstrating active synchronous neck rotation.

Fig. 8-C: Showing active neck flexion postoperatively.

FIG. 8-C

The origin was led subcutaneously to the mastoid process and the superior nuchal line, where it was sutured. The pectoralis major was sutured at intervals to the paralyzed sternocleidomastoid, so that as many of its muscle fasciculi as possible would be kept at a functional working length. The neurovascular pedicles came to rest against the substance of the remaining clavicular portion of the pectoralis major. This slight remaining portion of the pectoralis major was therefore incised to loosen the pedicles, since the function of the muscle had already been sacrificed. The insertion of the pectoralis major was sutured to the periosteum of the third and fourth ribs just lateral to the sternum. The muscle now lay with its insertion on the upper rib cage, near the mid-line, so that it crossed the region of the sternoclavicular joint, where it was sutured and was attached broadly to the mastoid process and adjacent fascial structures (Fig. 9).

The subcutaneous surface of the muscle lay against the deep neck structures and

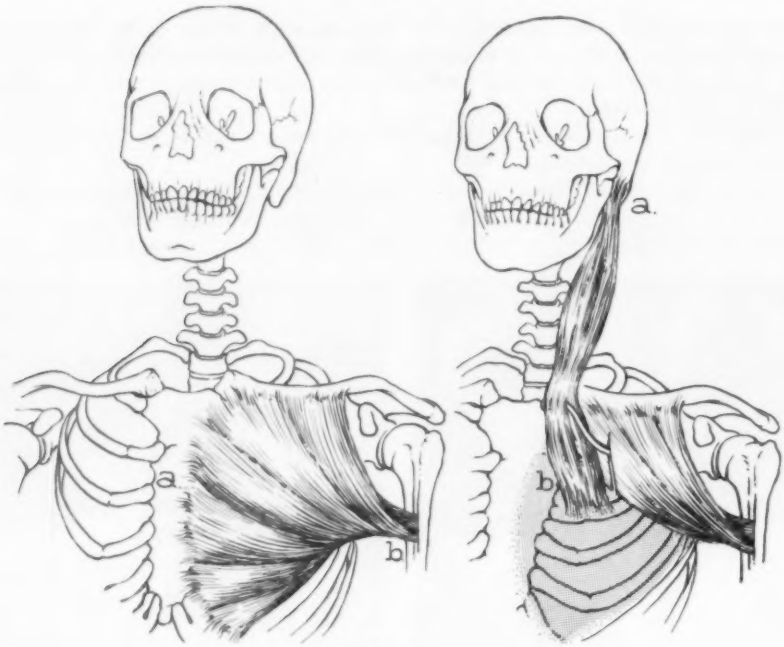

FIG. 9

Pectoralis major transposed to extend from the mastoid process to the third and fourth ribs, reinforcing neck flexion and head balance. *a*, origin; *b*, insertion.

the chest wall. In other words, the muscle was upside down and hind side before. After the procedure had been accomplished bilaterally, it was planned to suture the muscles to one another across the mid-line to give adequate strength and a more direct pull. This was postponed to allow the muscle strength to increase and the new attachments to become firm. It was obvious after the first two weeks that the contemplated final step had been in error, for the two muscles rapidly developed synchronous action, so that they lifted the head together, but on neck rotation contracted alternately as true agonists and antagonists.

At the present time, this boy has almost normal head balance and control. He can easily lift his head forward when supine or flex it from the hyperextended position. He is no longer afraid of losing his head balance, and he plays actively with other children. There is still the original cervical lordosis, but it has not increased. The transposed muscles have a somewhat larger volume than the normal sternocleidomastoid muscles, but are not unsightly.

No other techniques to aid in this problem have been reported, to the best of our knowledge. The only other alternative to muscle transposition in this case would have been fusion of the cervical portion of the spine. This would undoubtedly have aided the problem, but with a much less complete restoration of function.

At this writing, opportunity has not presented itself to replace neck extensors in a similar manner. However, the latissimi dorsi are sufficiently long and mobile for this purpose. They would extend from the thoracic ribs to the nuchal line.

MUSCLE TRANSPOSITION TO IMPROVE MASTICATION

L. S., aged six, was admitted to Shriners' Hospital in September 1952. He had suffered paralytic poliomyelitis in November 1950. There was some residual paralysis

FIG. 10-A

FIG. 10-B

Fig. 10-A: L. S. Boy chewing with the help of his hand on the back of his head and his chin forced against the chest.

Fig. 10-B: Postoperative photograph of boy, taken during the act of chewing a sandwich. Note that the chin is unsupported and is free of the chest.

in his left leg, but this was gradually decreasing and was no longer a problem to him. There was also complete loss of fifth motor nerve muscle power on the left, with a minimal trace on the right side. No activity of the temporal muscle could be felt, but there was a trace of the right masseter. When the examiner placed his fingers between the boy's molar teeth, he could not bite hard enough to cause the examiner pain. The bite power was so slight that it was necessary for the boy to rest his chin upon his chest and strike

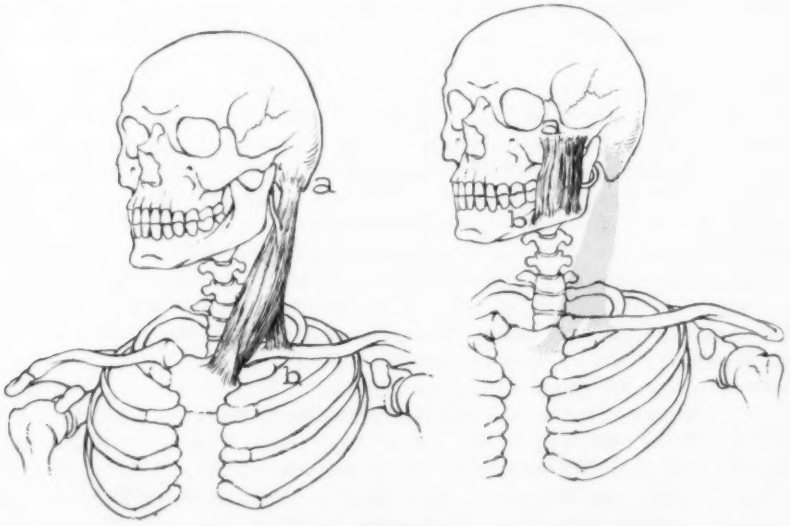

FIG. 11

Sternocleidomastoid transposed to extend from the malar to the mandible, reinforcing mastication. *a*, insertion; *b*, origin.

FIG. 12

Demonstrating the sternocleidomastoid detached from the mastoid and from the clavicle, with nerve supply and blood supply isolated.

the back of his head with his hand to bite a piece of bread. He could not chew hard candy. His parents did not allow him to eat away from home except under ideal circumstances, because of his odd manner of eating and the resultant attention from curious onlookers. The mandible moved weakly to the right, but not to the left. The mouth opened easily.

It was decided to move the sternocleidomastoid bilaterally to replace the masseters. At the outset, it was recognized that the trapezius function might be altered and this was discussed with the parents. They readily agreed that, if the procedure were successful, the gain would outweigh the possible loss.

The sternocleidomastoid was therefore transplanted bilaterally. Great care was taken not to injure the internal jugular vein, which lies directly below the muscle. The smaller occipital, great auricular, and cutaneous cervical nerves were carefully identified, so that the muscle could be retracted from under them and drawn upward. The mastoid attachment was sectioned and the eleventh nerve, as well as the major arterial blood supply, was carefully preserved. The dissection was carried forward and the subcutaneous tissues of the face were undermined. The mandible was exposed just anterior to the masseter insertion and the lower anterior border of the masseter. Care was taken to dissect in line with the radiating branches of the seventh cranial nerve and many of its branches were uncovered. The previously freed muscle was then transferred forward, after it had been partially disengaged from the eleventh nerve and after its origin had been flattened out. In most cases, it is necessary to disengage one muscle fasciculus of this multiform muscle from the nerve if it is to be moved forward.

The origin was then sewed to the origin of the masseter and the deep fascial tissues over the malar. The muscle belly of the sternocleidomastoid was sewed to the anterior border of the masseter and to the insertion of the masseter and periosteum of the mandible.

The muscle is always too long and the excess may be cut off or tucked under the jaw. We advise against cutting it off too freely (Fig. 11).

After operation the result was discouraging until the fourth week when the transplants began to gain strength. By the sixth week, the patient could leave teeth marks on the examiner's fingers, chew bread, and eat hard candy. The power has gradually improved since that time. When he was seen three months after operation, it was noted that power in the upper trapezius fibers was absent bilaterally, although he retained good range of shoulder abduction with some loss of strength in the upper range.

When he was seen one year after operation, the boy had regained his trapezius power. However, his strength of bite had not appreciably changed from what it was at three

FIG. 13

Demonstrating attachment of the sternocleidomastoid from the malar to the mandible.

months. The bulk of the sternocleidomastoid, however, had become less conspicuous.

Since that operation, another has been performed on a girl (B. K.) who had had poliomyelitis five years previously and whose jaw power was so weak that she had difficulty in completely closing her mouth.

To avoid facial scarring, Dr. Harry Blackfield, Consultant in Plastic Surgery for San Francisco Shriners' Hospital, was asked to develop the exposure. A typical face-lifting incision was used, the incision being made along the lobe of the ear with slight elongations in the hair line, both anteriorly and posteriorly. Thus the face incision used on the boy was avoided (Fig. 7 and 8).

The actual procedure is slightly more difficult. An additional incision must be used at the junction of the middle and lower thirds of the neck, approximately three to four inches (eight to ten centimeters) long, in order to disengage the lower end of the muscle. This girl also initially lost her upper trapezius power bilaterally, but after three months it was recovered. The eleventh nerve, as it leaves the sternocleidomastoid en route to the trapezius, is placed on stretch, but is not cut. Section of the nerve would facilitate the procedure, but is not necessary and therefore not recommended.

The postoperative results have been very good. She is now able to close her mouth satisfactorily and eats much better than she did previously. About three weeks after operation, she said that she could chew the crust of French bread. She can now bite into an apple and is chewing gum as an exercise. Her power is slowly increasing, after four months.

To our knowledge, no similar techniques to aid in mastication have been described. Difficulty in mastication is admittedly an unusual circumstance, but the fact that we

have operated on two such patients and know of four others with less severe involvement suggests that there are probably a good many persons so afflicted throughout the country.

DISCUSSION

The pectoralis major transposition, performed as described by transplanting the insertion to the acromion or coracoid process and the origin to the biceps tendon or through a drill hole in the ulna, is a very satisfactory procedure.

Patients gain elbow flexion, so that they can feed and dress themselves. They can also care for many of their other daily needs. However, one should not expect these transplants to provide great strength. The greatest amount of strength shown in any of our cases was in a twelve-year-old boy who was able to hold eight pounds at 90 degrees and to lift five pounds with the elbow fully extended. This, of course, does not represent the actual force which the transplanted muscle can develop, since the weight is held in the hand and the elbow is working on a short-lever arm just in front of the joint.

The advantages of moving both ends of the muscle in this transplantation are that the muscle is kept straight, so that force can be transmitted in a straight line and the pedicle is relieved from tension, for the pedicle is not pulled down so far toward the elbow.

In this transplantation, as well as in transplantation of the latissimus dorsi, it is important to maintain fiber length by sewing the edges of the muscle, where possible, to the proposed site of insertion and to the belly of the muscle being replaced. These muscles are not fibers of one large muscle bundle like those of the sternocleidomastoid, and their various segments should all be pulled out and kept to as great a length as possible. If the greatest number of muscle fasciculi possible are not kept at their normal functional length, it is only logical to expect the transplant to lose strength, for it has lost effective functional length of a portion of its volume.

Muscle-fiber length is important, for the muscle must be capable of sufficient contraction range to be able to reproduce all, or an effective portion, of the previous range of motion of the involved joint. Exact fiber lengths have not yet been worked out in detail for all muscles. However, it is not hard to estimate relative comparative muscle-fiber length. Muscles contracting through the same distance have fibers of the same length; and all fibers of a single muscle are the same length.[7]

There is often considerable difference of opinion between the theorist and the practical clinician concerning the tension of muscles and tendons at the time of transplantation. From the clinician's point of view, transplantations do best when placed under considerable tension. They should not be placed loosely. How tense should they be? This is difficult to answer in words. The pull must not be to the point of muscle-tearing, but certainly to 75 or 80 per cent. of muscle tension possible of attainment.

The average muscle in man is similar to his hamstrings or heel cords. These are constantly suffering from mild connective-tissue contracture, since they are seldom stretched to their limit. After transplantation, although they may remain tight at first, they rapidly stretch out to their proper length.[1]

A further favorable factor is the well known ability of all fibrous tissue to stretch and increase its length or circumference. Certainly tendons and interstitial connective tissue of muscles share in this basic ability.

Therefore, it becomes apparent that slight overstretch at the time of surgery is easily accommodated by physiological adaptation and is not an error. On the other hand, too loose placement may allow myostatic contracture to develop, with consequent reduction in power.

Care should be exercised to provide a straight line of pull whenever possible, so that these muscles will not lose power-transmitting pull around corners or through tight constricting pulleys. Muscle volume and the quality of the transplanted tissue must be sufficient to accomplish useful function. We have, in one instance, exposed the pectoralis

major in a patient with arthrogryposis and decided that the muscle would be too ineffective to justify transposition.

All muscles that are too long may be cut down at their insertion or origin. There is no reason that the lower third of the muscle distal to the entry of vessel and nerve cannot be resected so that efficient muscle length may be maintained. On the other hand, a portion of the origin can be resected if desired. The sternocleidomastoid transplantation for replacement of the masseter carries with it the possibility of trapezius weakness. This occurs because of the necessity of placing a stretch on the branch of the eleventh nerve to the trapezius as it leaves the sternocleidomastoid. Although the trapezius may recover its strength, possible weakness of this muscle should not be underestimated when the matter is discussed with the patient. Transplantation of the sternocleidomastoid laterally to the acromion has not resulted in this complication.

The other recorded transplantations carry no secondary risks, if they are carefully executed and if the muscles chosen for transplantation are not doing an essential motor job where they are normally located. In our experience the muscle transplanted, although functionally active and of sufficient power for light use, never equals in power the muscle being replaced or the transplanted muscle in its normal location.

In our experience, muscle re-education after tendon and muscle transplantation has been unnecessary. The awareness of a new function for an individual muscle does not need to be drilled into consciousness. The patient usually knows instinctively and without training or suggestion how to make the transplant function. The ease in learning and dissociating the old patterns from the new and desired patterns is more easily acquired by one person than another; and the continued development in consciousness and final relegation to subconscious activity may be facilitated by repeated activity.

The performance of any given transplant can be improved by suitable progressive-resistance exercises or an assisted progressive-resistance exercise program. However, even without special techniques to speed increase in work output, these same transplants over a period of time will generally become sufficiently strong to provide good function even though they are not at peak strength.

It is well known that muscles are not represented as such in the brain. Motions are, however, represented as motions [14]; and it would appear that the brain is capable of direction, regardless of the muscle used to carry out the desired movement. The important consideration is that active muscle, which is capable of contracting and accomplishing the desired brain pattern, be present. In other words, muscles are not necessarily specific for the function which they are performing. Most upper-extremity, as well as lower-extremity, movements can be made by contracting associated muscles or by contracting agonist and pseudo-antagonist at the same time, as is seen when joints are fixed in certain attitudes.

It is widely recognized that pseudo-antagonists make excellent transplants. Even true antagonists can be utilized to institute the specific antagonistic motion in question; for instance, the triceps for the biceps and the hamstrings for the quadriceps. It would appear from the cases here reported that this basic concept is true. There may be exceptions, but we have not yet encountered them.

There are undoubtedly many other applications for the principle of transposition. A few months ago, Dr. Paul Grigorieff of Eureka, California, suggested to us the possibility of using the sternocleidomastoid to replace the orbicularis oris in a case of poliomyelitis showing a lesion of the fifth and seventh cranial nerves. In reviewing the literature, the authors discovered that this use of the sternocleidomastoid had been previously reported [8,9]. However, it had never been attempted by moving both origin and insertion to suitable sites. This has been recently accomplished by the authors as a replacement for the orbicularis oris but is not yet ready for evaluation (Fig. 14). The early function of the transposed muscle is encouraging

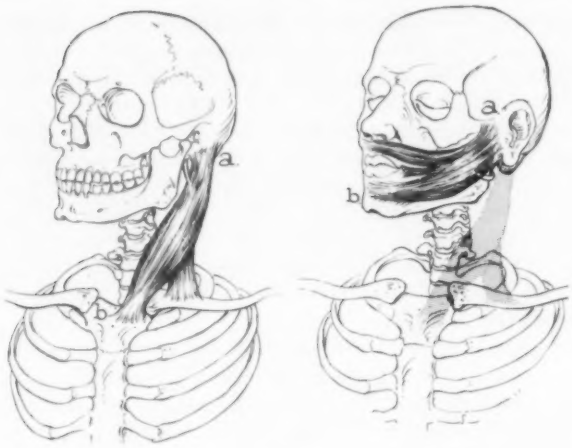

FIG. 14

Sternocleidomastoid transposed to extend from fascia anterior to ear and outer zygomatic arch to lips replacing orbicularis oris. *a*, insertion; *b*, origin.

In reference to other possible transpositions of muscles, we suggest that the latissimus dorsi could be used in isolated instances as an extensor of the head and neck; and that in some isolated cases the pectoralis major could be transposed posteriorly to make an efficient elbow extensor. Anatomically, the gracilis and adductor longus could be transferred to replace a paralyzed rectus abdominis.

Undoubtedly there will occur to orthopaedic surgeons many other uses of this principle for the reinforcement or replacement of muscle. If the basic principles are observed, transpositions will be successful. Before considering such transpositions, one should be certain that the muscle to be transplanted does not represent the only remaining motor for a vital function which it is accomplishing in its original site. If this is the case, it is unsuitable for transposition.

The procedures used in the cases mentioned in this article may be described briefly as follows.

PECTORALIS MAJOR TRANSPOSITION

Incision

1. An incision curved along the axillary border of the pectoralis major from approximately one inch (2.5 centimeters) distal to the margin of the axilla to one and a half or two inches (four or five centimeters) from the mid-line.

2. A straight three to four-inch (7.5 to ten centimeters) incision along the deltopectoral groove, starting one inch (2.5 centimeters) above the deltoid tubercle.

3. A medial incision five to six inches (12.5 to fifteen centimeters) long, paralleling the medial belly and tendon of the lower third of the biceps muscle. This can be swung across the antecubital fossa, but usually it is unwise to unroof the insertion of the biceps tendon unnecessarily.

Procedure

Through the chest incision the lower two thirds of the pectoralis major and its tendinous insertion into the humerus is freed from subcutaneous tissue. It is carefully separated from the pectoralis minor in the distal portion of the wound, and the plane between the muscles is widened from below upward toward the tendon of insertion. In this manner an important branch of innervation is found (if it is present, as it usually is) winding around the outer edge of the muscle. This branch dives through the pectoralis minor and comes up curving around the axillary edge of the pectoralis major. The major innervation of the pectoralis major and its blood supply are seen as the muscle is detached inferiorly. It lies applied to the undersurface of the pectoralis major. As the muscle is freed from its origin, several large perforating vessels are sectioned. These are not of any importance in preserving the viability of the muscle. After lifting the origin of the pecto-

ralis major, one can readily determine the amount of muscle dependent upon this portion of the mobile nerve and blood supply. This has been nearer one half than one third of the muscle in our experience. The insertion is then exposed through the upper incision over the humerus, and the insertion of the muscle to the humerus is detached. At this point the muscle is separated in line with its fasciculi across its surface, so that the lower portion to be mobilized is detached from the upper portion of muscle, which is left behind. The nerve supply and blood supply lie upon the undersurface of the pectoralis major and division without damage is relatively simple if one carefully inspects the nerve and blood supply from time to time as the division is made. The insertion can be detached in such a way that the clavicular fibers remain attached, or it can include the entire tendon. If the entire tendon is used, and the clavicular fibers are detached from it, they are unable to function because they are sectioned from their point of insertion. No functional harm is done, and the annoying, internally rotating action of these fibers associated with elbow flexion is overcome by inactivating the upper half of the muscle. The divided muscle is then attached to the body only by its neurovascular pedicle. It is wise to check the pedicle location while working by the use of a muscle stimulator. In this way work is done more rapidly and with less danger of doing irreparable damage.

Through the medial lower-arm incision, the lower half of the biceps belly and tendon is freed subcutaneously. A subcutaneous tunnel is made upward to the humeral incision, which was developed when the insertion was detached from the humerus. The coracoid process is also uncovered by working upward through this incision. The chest origin of the muscle is then drawn through the tunnel so that it lies over the lower biceps. It is sutured with No. 3 braided silk or other suture material, as desired, to the tendon of the biceps and the lower biceps muscle. The muscle may be attached through a drill hole directly to the radius or ulna, if desired. Care is taken that the individual fascicula of the pectoralis major are sewed at their greatest anatomical length to maintain them at their most functional length, so that unnecessary shortening of muscle units is prevented. The insertion is then sutured to the coracoid process and to the origin of the short head of the biceps. Thus, the entire muscle is placed under tension. If the tendon of the pectoralis major insertion is so long that the desired tension cannot be obtained by suturing its cut end into the coracoid, it is cut to the desired length. At this point, it can be noticed that the pedicle is relieved and made more lax by relieving some of the downward pull placed upon it initially when the muscle was sutured to the lower biceps.

We have moved the entire muscle when only the upper half seemed normal. At first, because of undue traction on the pedicle, the muscle did not contract. After three to four months the muscle works well, but since the fibers of the upper half of the muscle are so short and reach only approximately half-way down the biceps, the net effect is not ideal. The tail of rectus abdominis fascia can be removed inferiorly to gain additional length. However, this is seldom necessary. All wounds are closed, and the arm is bandaged in a modified Velpeau dressing, with the elbow at right angles. This is used for from two to four weeks, and is then replaced by a sling at right angles.

PECTORALIS MAJOR TRANSPOSITION TO REPLACE STERNOCLEIDOMASTOID MUSCLES AND ASSOCIATED NECK FLEXORS

Incisions

1. An incision along the axillary border of the pectoralis major as previously described, except that the inferior tail of the incision is curved upward to allow wider skin retraction.

2. A three-inch to four-inch (7.5 to ten centimeters) incision along the deltopectoral groove, as previously mentioned.

3. A curved incision in the creases of the neck, extending from just above the sternoclavicular joint four to five inches (ten to 12.5 centimeters) upward and outward at about the junction of the lower and middle thirds of the neck.

4. An incision over the mastoid process approximately two inches (five centimeters) long, extending from the mastoid process along the nuchal line.

Procedure

The pectoralis major is isolated, freed from the subcutaneous tissue, and detached at its insertion as described. However, in this procedure the upper three fourths, or the entire muscle, is freed. It is, however, mobilized so that it lies attached to the body only by its neurovascular pedicle. The pedicle is checked with an electric stimulator from time to time to make certain that it has not been damaged. Through the lower neck incision, the sternocleidomastoid is outlined from its clavicular insertion as far upward as possible. Care is taken not to damage the cutaneous nerves lying across the surface of this muscle, or the eleventh cranial nerve, especially if it is going to an active trapezius.

Through the scalp incision, the mastoid portion of the sternocleidomastoid is outlined, and this incision is connected subcutaneously along the sternocleidomastoid with the lower neck incision. The lower neck incision is tunneled to communicate widely with the chest incision. The chest origin of the pectoralis major is then drawn upward to the mastoid process. Excess muscle is trimmed as may be necessary. Usually there is very little more than one needs. We have found that there is less tension on the neurovascular pedicle of the pectoralis major, if this muscle is turned upside down as it is sutured into the mastoid process, nuchal line, and upper sternocleidomastoid. Its insertion is attached to the costochondral cartilages of the second and third ribs distally, being led over the clavicular insertion of the sternocleidomastoid, where it is also fixed with suture material. In this manner the chest origin of the pectoralis major is sutured to the mastoid process and the adjacent nuchal line, while the humeral insertion is sutured to the costochondral cartilages of the second and third ribs. Several sutures are taken attaching the sternocleidomastoid and the pectoralis major to maintain proper fiber length. The pectoralis major is rolled approximately two thirds of the way around the lower two thirds of the sternocleidomastoid, so that the original contour of this muscle is in part restored. All wounds are closed in layers.

A Velpeau dressing is applied to maintain the arm at the side, and the head and neck are included in this dressing, the head being tilted slightly toward the side operated upon. This dressing is maintained for two weeks. Following this, a light collar may be worn for an additional two weeks if desired, although we have not found this necessary.

LATISSIMUS DORSI TRANSPOSITION FOR ELBOW FLEXION

Incisions

1. Along the posterolateral border of the latissimus dorsi from the posterior edge of the axilla inferiorly to approximately two or three inches (five to 7.5 centimeters) above the iliac crest.

2. Anteriorly along the deltopectoral groove from deltoid tubercle to the coracoid process.

3. Along the medial margin of the lower half of the biceps and its tendon.

Procedure

Through the dorsolateral trunk incision, the lateral edge of the latissimus dorsi is isolated. The subcutaneous tissue is freed over the entire surface of the muscle and the edge of the muscle is lifted, care being taken that the serratus posterior inferior is not included with the latissimus dorsi. A flap of lumbodorsal fascia can be taken extending to the iliac crest, if desired. In lifting the origin cephalad, it is very easy to slip under the serratus anterior, but if the edge of the latissimus dorsi is identified, not only inferiorly, but also superiorly, this is easily avoided. The thoracodorsal nerve and blood supply attach themselves to the undersurface of the latissimus dorsi at the junction of its upper and middle thirds. Both blood supply and nerve supply are single and supply the entire

muscle, unlike the supply of the pectoralis major, in which often many small filaments of nerve need to be preserved as they pass through the underlying pectoralis minor. A large vein branches from the surface of the latissimus dorsi to the serratus anterior. This is cut and freed from the serratus anterior to mobilize further the lattisimus dorsi pedicle. If additional pedicle length is desired, an extra length of almost two and a half centimeters can be secured by incising the scapular head of the triceps and freeing it from its origin. It is later reattached if this is done. The insertion of the muscle is sectioned from the humerus, and the muscle is then detached except for its neurovascular pedicle. The pedicle is checked with an electric stimulator as necessary during the surgical procedure.

The deltopectoral incision is now opened and the coracoid process is exposed. The pectoralis major insertion is identified in the wound. Through the medial humeral incision, the biceps tendon and the lower half of the biceps muscle are freed from the subcutaneous tissue, and the wound is tunneled under the pectoralis major insertion to meet the upper humeral incision. The upper humeral incision is then tunneled with care for the brachial artery and major nerve trunks, so that it connects with the upper portion of the dorsolateral incision. At this point, the origin of the latissimus dorsi is drawn through the tunnel and forward to the deltopectoral incision and is thence led subcutaneously down the arm to the medial humeral incision. The origin of the muscle is sutured to the biceps tendon and lower half of the biceps muscle in the same manner that the pectoralis major is attached. Excess muscle is removed, as much being retained as is consistent with good postoperative tension. The insertion is sutured securely to the coracoid process and the adjacent tissues. The pedicle thus passes on the chest side of the humerus between bone on one side and the neurovascular bundle of the arm and short head of the biceps on the other. The muscle lies in its new position from the coracoid to the radial tubercle beneath the pectoralis major tendon. All wounds are closed in layers, and a Velpeau dressing is used after operation (as with the pectoralis major transposition) for from two to four weeks. There is no harm in allowing the patient to contract the muscle actively as early as ten days, probably earlier if no strain is placed upon it by extending the elbow. We prefer to continue a sling until approximately six weeks after operation.

LATISSIMUS DORSI TRANSPOSITION FOR ELBOW EXTENSION

Incisions

1. Dorsolateral from the posterior axillary margin to approximately two or three inches (five to 7.5 centimeters) above the iliac crest, paralleling the lateral border of the latissimus dorsi, and one to two inches (2.5 to five centimeters) medial to its lateral edge.

2. Either medial or lateral along the lower half of the triceps and olecranon. (The lateral exposure is easier.)

3. Two-inch (five-centimeter) incision over the posterior edge of the acromion.

Procedure

The latissimus dorsi is freed, isolated, and lifted, as previously described, so that it lies attached by only its neurovascular pedicle. The lower portion of the triceps is freed subcutaneously, as is the olecranon. The humeral incision is tunneled subcutaneously to the upper edge of the dorsolateral incision. The origin of the latissimus dorsi is drawn subcutaneously to lie over the lower portions of the triceps and olecranon. It is sutured to the lower third of the muscle and to the bone, as desired. The acromion having been previously prepared, the insertion of the latissimus dorsi may be drawn beneath the posterior deltoid through a stab wound in the upper edge of the muscle, or it may be placed over the muscle. It is sutured securely to the acromion and adjacent tissues. All wounds are closed in layers. The arm is maintained in extension for a period of two or three weeks, after which progressive flexion may be allowed.

STERNOCLEIDOMASTOID TRANSPOSITION TO ACROMION

Incisions

1. An incision curved at the junction of the middle and lower thirds of the neck from the clavicular insertion of the sternocleidomastoid four to five inches (ten to 12.5 centimeters) long, following the neck creases.

2. A three-inch (7.5 centimeters) incision over the trapezius insertion to the acromion.

Procedure

Through the neck incision, the sternal and clavicular heads of the sternocleidomastoid are isolated and divided, care being taken not to damage the internal jugular vein which lies beneath this muscle. The sternocleidomastoid is dissected free, the cutaneous cervical and great auricular nerves being exposed. The eleventh cranial nerve, as it leaves the inferior margin of the muscle, is carefully preserved if there is any trapezius function. The muscle can now be lifted cephalad, being freed from the cutaneous nerves as they cross its course. Through either an extension of the original incision or the acromial incision, the outer fibers of the trapezius are isolated as they come into the acromion. The sternocleidomastoid is then rerouted in such a manner that there is a direct line of pull from the mastoid process to the acromion and it is then sutured to the trapezius as far laterally as this muscle normally inserts. It is attached to bone, as well as to the overlying fascia. The arm is placed in a modified Velpeau bandage. The head and neck may be included if desired, and they are tilted toward the side operated upon. It is not necessary to maintain this position more than two weeks. (We have done only one of the procedures described, so that the postoperative care is in no wise settled.) This transfer works very well in our case, although here the scapula was also tied to the rib cage with fascia, as described in the case of E. T.

STERNOCLEIDOMASTOID TRANSPOSITION TO REPLACE MASSETER FUNCTION

Incisions

1. An incision four to six inches (ten to fifteen centimeters) long in the lower portion of the middle third of the neck in the line of the skin creases.

2. At the mastoid process and along the nuchal line an incision approximately two or three inches (five to 7.5 centimeters) long.

3. Curved, with its convex margin facing outward over the cheek, at the level of the zygoma and along the zygomatic arch, an incision approximately three inches (7.5 centimeters) long.

3a. Instead of incision 2. and incision 3., a face-lifting incision, extending around the lower third of the ear and carried forward in the hair line anteriorly above the zygomatic arch, and posteriorly in the hair line above the mastoid process.

Procedure

Through the first incision the sternocleidomastoid is mobilized down to the clavicle and is resected from the clavicle, care being taken to protect the adjacent structures, especially the internal jugular vein. It is then carefully mobilized upward toward the mastoid prominence. The cutaneous cervical, great auricular, and smaller occipital nerves are found and protected. The exit of the eleventh cranial nerve from the sternocleidomastoid is exposed. The incision near the mastoid process is developed, the sternocleidomastoid being exposed above, and the posterior border of this muscle being developed. The mastoid attachment of the muscle is usually detached at this time. The anterior border of the muscle is very carefully dissected, and with a muscle stimulator, the point of nerve entry to the muscle is determined. Great care must be taken at this time not to

damage the nerve or blood supply, for the blood supply especially is easily damaged in this muscle. We plan to leave extra fibrous tissue at this point without trying to limit the pedicle to one vessel. The pedicle will then be found long enough to allow the muscle to be brought over in front of the ear. The pedicle reaches the muscle at the junction of its upper and middle thirds, or slightly higher.

The upper flap of the neck incision can be developed into the face, or there may be another incision under the angle of the jaw. In any event, the plane of subcutaneous tissue above the branches of the seventh nerve and parotid gland and its duct is found. It is lifted to the anterior edge of the masseter and then to the mandible and zygoma. Once the masseter border has been located, the overlying soft tissue can be carefully dissected in the direction of the fibers of the seventh nerve, and they are easily identified. The parotid duct is found in the field, but, if its location is remembered, it is easily avoided. If dissection is carried along the course of the nerve and never across the direction of its fibers, the seventh cranial nerve and its branches will not be damaged. The mandible and zygoma are bared and the muscle is led into the face, its sternal and clavicular heads approximating the mandible and its mastoid insertion approximating the zygoma. The spinal accessory nerve may need to be unwound from the upper muscle fasciculi by splitting from above downward to the pedicle entrance. The nerve may then be easily extricated from the snubbing action of the muscle. This procedure of nerve freeing is not always necessary. The mastoid attachment of the sternocleidomastoid is sutured to the zygoma and adjacent fascia, the suture of choice being used. We have used No. 3 braided silk. It is also sutured to the anterior edge of the masseter, and the extra muscle from the origin is tucked under the mandible or resected, as desired. Several sutures are taken to attach the sternocleidomastoid to the periosteum of the mandible. The wounds are all closed, and a head and neck pressure dressing is applied, care being taken not to use too much pressure.

One should expect oedema of the cheek and eyelid for from five to eight days after operation; this may often close the eye. Some slight oedema will usually persist for two or three months. The face may appear asymmetrical for several months, but so far in our cases symmetry has been regained. (In the face-lifting incision, the skin is lifted from the base of the ear and dissected downward, scissors being used to clip the skin from the subcutaneous tissue. Adrenalin packs hold hemorrhage at a minimum, but it should be remembered that it is unwise to use them around the neurovascular pedicle, for they will impair muscle circulation. The bridge of subcutaneous tissue below the ear, left by this technique, is undermined or divided when the muscle is brought into the face. The pedicle should not be stretched and all muscle fibers will not lie in a straight line. Some of them will be straight from origin to insertion, but many will be bowed at the point of entrance of the neurovascular bundle. This technique leaves no face scar and is ideal for a woman, but there is an increased difficulty in preparing an adequate bed for transposition.) It is the authors' personal opinion that anyone performing this procedure should first check the details of the sternocleidomastoid anatomy carefully on a cadaver, for there are several pitfalls which, once noted by the surgeon, are easily avoided.

STERNOCLEIDOMASTOID TRANSPOSITION FOR FACIAL PARALYSIS

Incisions

1. A four-inch to six-inch (ten to fifteen centimeters) incision in the lower portion of the middle third of the neck, paralleling the skin creases of the neck.

2. A two-inch to four-inch (five to ten centimeters) incision at the mastoid process.

3. A face-lifting incision around the edge of the ear, extended both anteriorly and posteriorly in the hair line.

4. Appropriate face incision one-quarter to three-eighths of an inch (one-half to one centimeter) long in the face at the corner of the lip and over the lip.

Procedure

This procedure is identical to the foregoing described under "Transposition of the Sternocleidomastoid to Replace Masseter Function", until the muscle has been completely freed and is lying on its neurovascular pedicle. The mastoid portion of the muscle is attached over the parotid and to the outer edge of the zygomatic arch, as well as below and just in front of the ear, care being taken not to damage the superficial temporal artery and branches of the seventh nerve to the eye. It is then led to the lip, where it is sutured. We have done but one such operation to replace the orbicularis oris and those facial muscles at the angle of the lip (the quadratus labii superioris, zygomaticus, caninus, and risorius). In our case, the sternocleidomastoid was divided into three tails. The superior tail was led through a subcutaneous tunnel in the upper lip across the mid-line and anchored through a tiny incision to the underlying normal orbicularis oris. The middle tail was partially resected, since it was too long, and its stump was sutured at the angle of the lip to the facial fascia and the general insertion of those muscles acting at the angle of the lip. The third tail of the sternocleidomastoid was led subcutaneously across the mid-line of the lower lip over the paralyzed orbicularis oris and across to the normal orbicularis oris, to which it was sutured through a tiny lip incision. Except for proper preparation of the sternocleidomastoid, as previously noted, this is not an extremely difficult procedure, although care must be taken to preserve the parotid gland and its duct. In some instances one or another tail of the sternocleidomastoid may need to be lengthened by a small extension of fascia lata. The patient here reported had difficulty for several months in cultivating the use of this muscle transplant. However, it now functions satisfactorily.

NOTE: We wish to acknowledge the use of the University of California Anatomical Laboratory, made possible through the cooperation of John B. deC. M. Saunders, M.B., F.R.C.S.

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DISCUSSION

DR. GEORGE J. GARCEAU, INDIANAPOLIS, INDIANA: This paper, as you undoubtedly realize, covers a great deal of territory. Discussing this paper is almost like discussing a sizeable section of Cunningham's *Text-Book of Anatomy*. A transposition of the origin or of both the origin and the insertion of a muscle is dependent for its success on the mobility of the neurovascular bundle. Transplantation of a part of a muscle

—for instance, of the inferior two thirds of the pectoralis major as was demonstrated—is possible only because that muscle has a dual innervation and blood supply. Some muscles have triple innervation and blood supply. In the particular operation of pectoralis major transplantation, success is dependent on three factors: a dual blood supply, a dual innervation, and a neurovascular pedicle which is mobile.

The authors have also considered the length of muscle fibers of the transplanted muscle. In this respect the muscle should compare favorably, of course, with the muscle that is being replaced, although there may be some exceptions, such as the masseter. Further study of muscle-fiber length seems to be indicated. A knowledge of muscle-fiber length should be of great help in estimating the tension under which the transplanted muscle should be placed. The danger of injury to the nerve and blood supply of the transposed muscle must be weighed. In transposition of the sternocleidomastoid, for instance, the surrounding structures could easily be injured. Injury of the large blood vessels under the sternocleidomastoid might be somewhat disconcerting.

The authors have opened a field which deserves further exploration. A thorough knowledge of the anatomy involved is necessary. Although I feel inadequate to discuss this paper, I thoroughly enjoyed reading it, and I am very grateful for having had the opportunity of studying the paper. I have read it at least fifteen times and I am going to read it again, because there is so much in it.

DR. WILLIAM T. MUSTARD, TORONTO, ONTARIO, CANADA: The term "muscle transposition", I think, is well taken, because there is considerable confusion in the literature concerning muscle transfers, muscle transpositions, and muscle transplantations. There is no such thing as a muscle transplantation; a muscle cannot be transplanted because its nerve supply and blood supply must remain intact. What is discussed here is a muscle transposition, and it is a very brilliantly executed operation. The shift of the pectoralis major, both its origin and its insertion, to reinforce a Steindler flexorplasty of the elbow, seems to me a very good operation. The transfer of the pectoralis into the neck was phenomenally successful. I have a patient, a child whose spine I fused five years ago; I wish I could "unfuse" the spine and perform this operation.

I think that, in the original paper, it was suggested that the latissimus dorsi be turned upside down and be put into the nuchal line to reinforce neck extension. This seems to me a very sensible thing to do. I have learned a great deal from this paper.

REPAIR OF THE MOTOR BRANCH OF THE ULNAR NERVE IN THE PALM * †

BY JOSEPH H. BOYES, M.D., LOS ANGELES, CALIFORNIA

The human hand is more than an *organ of grasp:* Its sensibility and specialized tactile surfaces make it also an *organ of sensation.* Yet these two attributes—the ability to hold and the ability to feel—which depend primarily upon the forearm muscles and the function of the median nerve, give the hand only the fundamental skills. Superimposed on these are the motions intrinsic to the hand itself which make it, in addition, an *organ of expression.* Our hands help us to make known our ideas and to mirror our feelings; for "By them we ask, we promise, we invoke, we dismiss, we threaten, we entreat, we deprecate, we express fear, joy, grief, our doubts, our assent, our penitence; we show moderation, profusion; we mark number and time." [1]

FIG. 1

Clawing from an ulnar-nerve lesion varies with the level of the lesion and the laxity of the proximal finger joints. Here motor paralysis of the intrinsics allows the normal long extensors and flexors to produce clawing because the proximal joints can hyperextend.

The intrinsic muscles, for the most part supplied by the ulnar nerve, give to the hand the quick, skillful, but less strong movements which characteristically result from the activity of muscles inserting near the center of motion of a joint. By contrast, the extrinsic muscles of the forearm, working through their tendons inserted near the end of the digit, produce a slower but more powerful effect. Loss of the fine motions from damage to the ulnar nerve is particularly disabling to the artist and to the craftsmen of the spinning, weaving, or engraving trades.

FIG. 2

From a dissection of the ulnar nerve in the hand. The course and method of branching are remarkably constant.

Loss of function from an

* Presented as a preliminary report at the Annual Meeting of the American Society for Surgery of the Hand, New York, N. Y., February 10, 1950. Case 8 in Table I has been added to the series.

† Revised manuscript received for publication February 21, 1955.

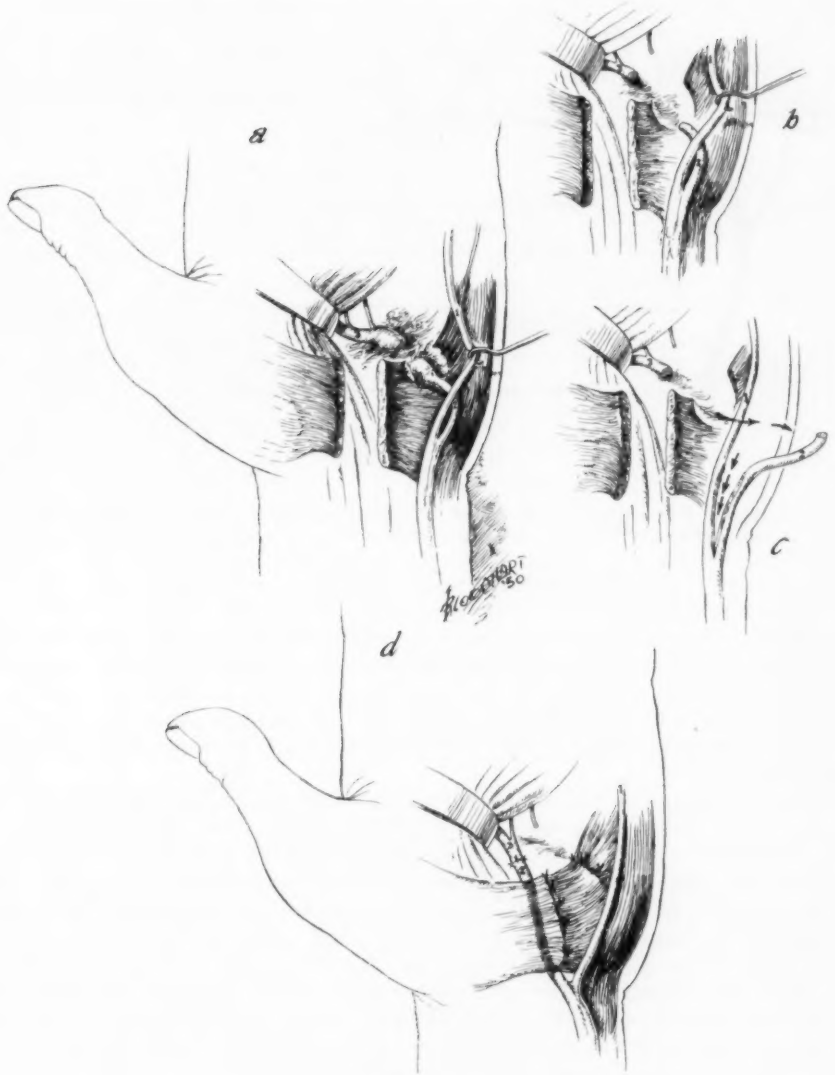

FIG. 3

Method of rerouting the motor branch of the ulnar nerve through the carpal tunnel to allow suturing where loss of substance is present.

ulnar-nerve lesion in the hand does not destroy the prehensile function of the hand nor its principal sensory area. Clawing is not a noticeable feature when the lesion is below the branches to the hypothenar muscle group. A lesion here may result only in loss of the lateral motions of one or two digits and weakness of the thumb from paralysis of its adductor muscle. Even this disability in the thumb is variable, due to the double nerve supply of the short flexor muscle which can compensate to prevent instability of the proximal joint. Lesions of the nerve at the wrist, leaving the extrinsic flexor function unopposed, are usually accompanied by clawing, although this is of little consequence unless the proximal finger joints are lax and allow a "cock-back" position to be assumed (Fig. 1).

The motor component of the ulnar nerve to the intrinsic muscles arises as a division

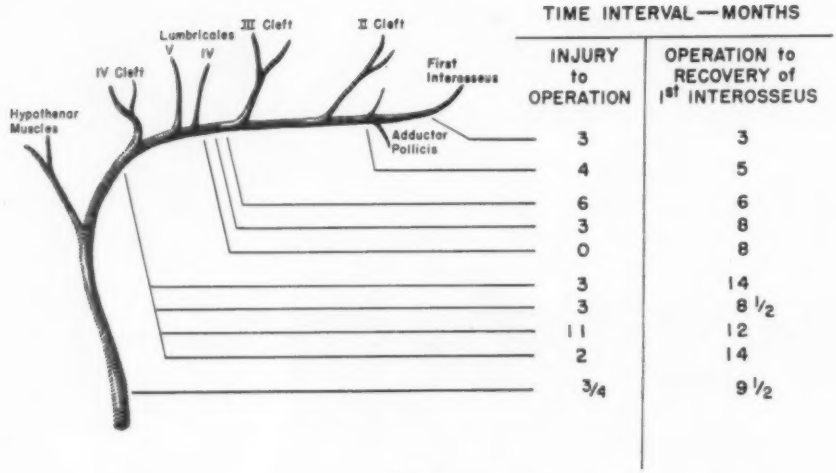

FIG. 4

Diagram to illustrate the rate of recovery of voluntary flexion in the first interosseus muscle, after repair of the ulnar nerve at various levels in the palm.

of the main trunk at the level of the wrist. It passes across the palm deep to the flexor tendons and is well protected throughout its course. Its location, as related to surface and bony landmarks, and its method of branching are remarkably constant. Many dissections, as well as stimulation of the nerve during operative procedures on the hand, have disclosed only one significant variation: In one instance, the branch of the nerve supplying the fourth lumbrical muscle was found to arise from the common digital sensory nerve to the fourth cleft instead of from its usual direct connection with the motor trunk deep in the palm (Fig. 2).

Exposure of the nerve from its origin as a branch of the main trunk at the wrist level to its mid-palmar portion is best made through a curved skin incision distal to, but parallel to, the thenar crease, which passes over the hook of the hamate to the flexion crease of the wrist where it crosses the crease obliquely and proceeds to the ulnar aspect of the lower portion of the forearm. The skin is reflected and the palmaris brevis muscle is divided at its insertion (that is, its radial side) and is reflected ulnarward so as not to disturb its nerve supply. The ulnar vessels are retracted toward the thumb; and, when the origins of the abductor digiti quinti, flexor digiti quinti, and opponens digiti quinti muscles are divided and the tendons of the flexor digitorum are elevated, the full course of the nerve can be seen from its origin at the pisiform to the mid-palm. Further exposure of its distal portion can be obtained by extending the incision to the index metacarpal and by elevating in one mass the flexor tendons and lumbrical muscles. With these displaced ulnarward, the nerve can be picked up where it passes through the transverse fibers of the adductor.

In civilian life, injuries to this nerve are usually caused by sharp instruments. A gentle freeing of the nerve, both proximally and distally to the point of damage, allows ample room for suture without tension. In gunshot wounds, or in wounds in which a loss of substance has resulted, which makes it difficult to approximate the ends, a rerouting of the nerve is accomplished (Fig. 3). The motor component is split from the trunk well into the lower portion of the forearm. The volar carpal ligament is then divided and the ulnar bursa, making up the lining of the carpal tunnel, is freed from the ulnar side of the carpus. The proximal end of the nerve is then displaced into the carpal tunnel and its route is shortened. By flexing the wrist, the proximal end can be brought to the mid-palm. The volar carpal ligament is resutured; and, in closure of the wound, the normal insertion

TABLE I

SUMMARY OF CASES

Level of Lesion	Case	Lesion	Duration of Paralysis	Operation	Recovery of First Interosseus (*Months*)	Remarks
Main trunk above hypothenar branch	1. Mr. K.	Carpal ganglion at pisiform.	7 mos.	Excision of ganglion	6	Full recovery.
	2. Mr. F.	Laceration.	6 mos.	Suture at level of hook of hamate		No follow-up.
	3. Mr. B.	Wound from ¼ in. drill penetrating capitate.	3 wks.	Suture	9½	Sensory trunk also repaired; recovered.
Distal to hypothenar branching	4. Mr. C.	Lifting strain, tender over hook of hamate.	Incomplete	None		Full recovery.
	5. Mr. T.	Laceration, marked clawing even with hypothenar working.	4 mos.	Neurolysis		No improvement at 6 mos.
			11 mos.	Resection and suture	12	Maintained normal position without clawing at 14 mos.
	6. Mr. K.	Laceration by porcelain faucet handle; had primary flexor-tendon repair.	3 mos.	Suture	8½	Less clawing at 5 mos. Normal hand, except spread between index and long finger lacked ⅝ in. at 18 mos.
Mid-palm	7. Mr. A.	Laceration.	3 mos.	Suture	14	Complete intrinsic recovery, except lateral motion of middle finger.
	8. Mr. G.	Laceration.	2 mos.	Suture at hypothenar origin	14	
	9. Mr. M.	Auto accident, avulsion by door handle.	Primary repair	Suture	8	Lateral motions ring and little fingers did not recover.
	10. Master K.	Laceration, plus severance of 4 tendons.	3 mos.	Suture, plus 5 sensory nerves 2 tendon grafts 1 pulley operation	8	Clawing still present.
	11. Mr. T.	Laceration through metacarpophalangeal joint middle finger.	1 mo. Incomplete	None		Improved at 3 mos.
	12. Miss F.	Laceration at pisiform, no clawing.	6 mos.	Suture	6	Less atrophy at 4 mos. Grip 80% at 14 mos. No lateral motion, long and ring fingers.
At or beyond adductor pollicis	13. Mrs. D.	Laceration by porcelain faucet handle.	4 mos.	Suture	5	Good thumb adduction, spread of fingers lacks ⅜ in. at 8 mos.
	14. Mrs. E.	Laceration.	3 mos.	Suture distal to adductor	3	

of the palmaris brevis is replaced. In some cases, when branches to the hypothenar muscles are still intact, gentle dissection and splitting off of the intact bundles will allow the branches to be saved and yet will permit the nerve to be rerouted into the carpal tunnel.

Suture of the freshened nerve ends is carried out by approximating the sheath with interrupted 000000 silk on small curved cutting needles. Regeneration takes place in an orderly way; and the results, as in most peripheral-nerve repairs, are proportional to the accuracy of the approximation and inversely proportional to the scarring and fibrosis present. Recovery of the nerve function is tested by noting voluntary activity of the easily seen and easily palpated first interosseus muscle (Fig. 4).

Although many operative procedures have been devised to restore some of the lost function when the intrinsic muscles are paralyzed, direct repair of the nerve is more desirable. Substitute motions as a result of tendon transplantations have a definite field of usefulness in the treatment of irreparable nerve lesions; but, when the disability is a direct result of damage to the nerve, all possible attempts should be made to repair it before resorting to alternative procedures.

A study of fourteen patients (Table I) with lesions of the motor branch of the ulnar nerve, classified as to the level of the lesion, illustrates the rate of recovery after suture of the nerve at the various levels. The results as shown by increased dexterity and function of the hand were most gratifying. Of eleven patients with complete severance of the nerve distal to its origin, two had lesions in the main trunk (that is, above the level at which the hypothenar branches are given off), four had lesions distal to the hypothenar branches, three had nerves damaged in the mid-palm, and two had severance of the nerve at the level of the adductor pollicis muscle. Only one repair was done as a primary procedure at the time of injury, the others ranging from three weeks to eleven months after injury. One patient could not be followed; the remaining ten were followed for at least a year. Evidence of recovery, that is, voluntary activity of the first interosseus muscle, was present in all ten. Two patients, with incomplete paralysis due to closed injuries to the palm, recovered full function in six months. One patient, with complete intrinsic paralysis of seven months' duration, recovered in six months when a carpal ganglion, intimately attached to the nerve between the pisiform and the hook of the hamate, was found and removed. Seddon has recently reported a series of these interesting lesions.

CONCLUSION

A study of patients treated for paralysis due to damage to the deep motor branch of the ulnar nerve in the palm shows that repair of the nerve is a practical procedure and that recovery of function takes place. Regeneration, as evidenced by voluntary activity of the first interosseus muscle, takes place in an orderly way and is present in from three to fourteen months, depending upon the level of the injury. Direct end-to-end approximation is usually possible; but, if it is necessary, the nerve can be rerouted through the carpal tunnel to overcome a large defect.

Function of the hand as an *organ of expression* is dependent upon the ulnar nerve. Repair and subsequent regeneration restores to the hand those motions so necessary to the artist and the skilled workman, without which, as Galen says, man could "no longer work as an artificer. . . . Neither could he follow the arts of peace, construct the pipe and lyre, erect houses, place altars, inscribe laws, and through letters and the ingenuity of the hand, hold communion with the wisdom of antiquity, at one time to converse with Plato, at another with Aristotle, or Hippocrates."

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NON-OPERATIVE TREATMENT, INCLUDING MANIPULATION, FOR LUMBAR INTERVERTEBRAL DISC SYNDROME *

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INTRODUCTION

Two decades have elapsed since Mixter and Barr brought to the attention of the medical profession the problem of herniation of the low lumbar intervertebral disc as one of the causes of low-back pain with sciatic radiation. The initial wave of enthusiasm for operative intervention as the specific therapy for the condition has ebbed, and operative intervention has assumed its rightful part in the treatment of the lesion.

Conservative or non-operative treatment is being given increasing attention by both orthopaedic surgeons and neurosurgeons. The opinion prevails that only a small percentage of the cases require surgical intervention.

Manipulation, as a form of therapy, for low-back disabilities has been used for many years with gratifying results. The British, as exemplified by Mennell, have done much in this field, and many men in the United States are advocates of manipulation.

Recently Ewer reported some excellent results from back manipulation in patients with low-back disabilities and radiation into the thigh only. He specifically advised against manipulation in patients with herniation of the intervertebral disc. One wonders at the sharp line of demarcation; in the light of our experience and that of others, this contraindication does not seem to be justified.

It would seem logical, therefore, for manipulation to be added to the other forms of non-operative treatment of the lumbar intervertebral disc syndrome. Neither time nor space permit a review of the many references in the literature to the use of conservative treatment of this disability, with and without manipulation.

Such authorities as Myron Henry, Fremont Chandler, J. Albert Key, R. H. Ramsey, and R. S. Henderson have reported their results and have expressed, at various times, preference for conservative treatment of patients with this disability.

Colonna and Friedenberg, in 1949, analyzed a series of twenty-eight patients having positive myelograms treated conservatively, but without manipulation, who were compared with a group of ninety-five patients treated operatively. Using freedom from pain as the major criterion for the success of treatment, they found that 60 per cent. of the patients in the operative group were pain-free and 29 per cent. of the patients in the non-operative group were pain-free. In the treatment of our present series of patients manipulation was an added phase of therapy. With the use of the same criterion and with a slightly shorter average period of follow-up in a larger number of cases, we are able to report satisfactory results in 64 per cent. of the private patients and 45 per cent. of the industrial patients.

Principles of Non-Operative Treatment

In general, the usual conservative treatment may be divided into four main components: (1) rest, (2) support, (3) rehabilitation exercises (with or without physical therapy), and (4) time. To these we have added a fifth—manipulation.

With the usual conservative treatment, one expects a gradual remission in subjective complaints and objective findings, and a slow but steady restoration of physical capacity. With manipulation added, in successful cases, immediate loss of sciatic pain is anticipated. The elimination of the major factor of pain allows a marked acceleration in the final phase

* Presented in part before the Pan-Pacific Surgical Association, Honolulu, Hawaii, October 14, 1954; based on a Scientific Exhibit at The American Academy of Orthopaedic Surgeons, Los Angeles, California, January 29 to February 3, 1955.

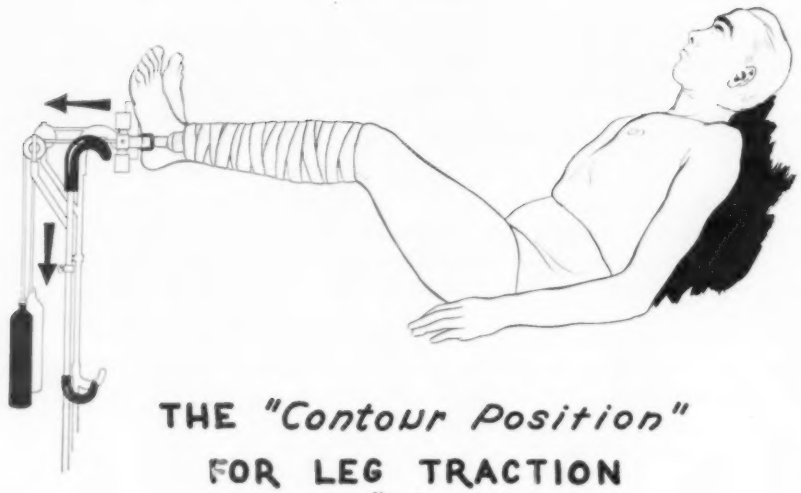

FIG. 1

of rehabilitation therapy and permits the wage earner to return to his work in a much shorter period of time. Thus, by the addition of the fifth component, the period of severe pain is dramatically terminated and the period of incapacity is reduced.

Basis of Report

This report is a result of an analysis of 285 patients in approximately a ten-year period who were deemed to have sufficient history and findings to warrant the diagnosis of a protrusion of a lumbar intervertebral disc.

In order to substantiate such a diagnosis, consideration was given to the type, onset, and localization of the low-back pain, the tenderness and the limitation of spinal motion (especially the flattening of the lumbar arc on forward bending), straight-leg-raising, reflex changes, sensory changes, motor weakness and atrophy, and the amount of incapacity. Routine roentgenographic studies of the lumbosacral spine were made of all patients; these were based on roentgenograms made through the following exposures: anteroposterior, lateral (with the patient standing), spot lateral focused over the lumbosacral area, right and left oblique stereoscopics, and one of the lumbosacral region at a 45-degree angle. Care was taken to evaluate the anomalies, infection and arthritis, spondylolisthesis and spondylolysis, fractures, tumors (both osseous and neurogenic), and osteoporosis in the differential diagnosis.

Myelograms were not made routinely before manipulation. It is our belief that the diagnosis can and should be made clinically, the myelogram being reserved for doubtful cases and for those patients upon whom surgery is to be performed for confirmation and localization of the lesion. Before a final diagnosis was made, a combination of at least four of the previously outlined positive findings were considered necessary. In many, all were present.

TREATMENT

Method

Nothing new or original is claimed for the treatment here described. The importance of strict adherence to the details of treatment is stressed. The conservative phase of the treatment in this series was under the direct supervision of the author and, in some cases, of a former associate *.

* Dr. J. W. Shumate.

FIG. 2

1. *Traction:* All patients are hospitalized and bilateral (skin) traction (six to ten pounds) is applied to each lower extremity with the patient in the "contour" position (Fig. 1).

2. *Manipulation under anaesthesia:* Sodium pentothal intravenously is used routinely.

FIG. 3

The patient is supine. The involved extremity is manipulated first. With an assistant firmly holding the shoulder of the side to be manipulated against the table and with the other limb likewise fixed to the table, the operator, from the opposite side of the table, rotates the limb internally, flexes and adducts the extremity, using the limb as a lever and adding to the force applied by thrusting with his other hand against the ilium in the direction of the leverage (Figs. 2 and 3). In the majority of patients an audible crunching and popping occurs. This procedure is then repeated on the opposite side. No other manipulations are done. Variations of this procedure have been and are being used by many surgeons as evidenced by the report of the St. Louis Group [11]. The "lumbosacral stretch" was described by Pitkin in 1937.

What happens during manipulation is a matter of speculation and has no real value in an analytical survey. However, this is being investigated and it is hoped that, at some future date, a report, substantiated by scientific proof, will be made.

Following the manipulation, the patient is returned to his bed, and traction in the same position is reapplied. This is maintained on an average for five days. Before ambulation is allowed, the patient is fitted with a spring-steel chair-type back brace. Women are given a laced-front corset with back steels. During the period of postoperative traction, the patient is cautioned to avoid rotatory twisting motions as a few patients who were asymptomatic in bed have had a sudden recrudescence of symptoms following an attempt to take something from a bedside table or the floor.

The patient will promptly inform the operator of the success or failure of the treatment. The sciatic pain is either relieved or persistent. Some gluteal pain on the involved side and a variable amount of backache of a different type is a common finding. The backache gradually disappears in a few days, but the recurrent gluteal pain, rarely more than annoying, may persist for a week or two.

Objective physical findings on the resumption of weight-bearing are noticeably improved. The range of spinal motion, with the restoration of the lumbar curve, is increased. Straight-leg-raising rapidly returns to normal. If the patellar or Achilles-tendon reflex was previously depressed or absent, the amplitude of either may be increased. It seems advisable, however, to allow healing to progress without interruption, and objective examination is deferred until after the first week of weight-bearing. In the convalescent period, the patient is allowed weight-bearing but at the slightest recurrence of symptoms, recumbence, for the time being, is resumed. No other physical activity is allowed for two to three weeks. He is instructed in flexion exercises for the back and how to bend and to lift — these procedures being carried out at home. He is allowed to return to work, depending on his occupation, in from four to six weeks. Heavy weight-lifting is avoided for several months. The brace is worn continuously during this period (average three months), with gradual removal, depending on the individual case.

Limitations of Therapy and Contra-Indications

1. We have arbitrarily limited the number of manipulations performed during the initial period of hospitalization to two in those patients in whom the first was unsuccessful — thirty-five patients (17 per cent.) were manipulated twice.

2. Patients with definite motor involvement of any degree were not subjected to manipulation. Weakness of the extensor hallucis longus was a relatively common diagnostic finding and was not included as a contra-indication.

3. Elderly patients with complicating cardiovascular disease or with roentgenographic evidence of spinal osteoporosis or marked degenerative changes were excluded.

4. Spondylolisthesis and roentgenographic evidence of laminar or pedicle defects were felt to be contra-indications to manipulation.

Complications

1. Secondary injuries resulting in the recurrence of symptoms occurred in eight

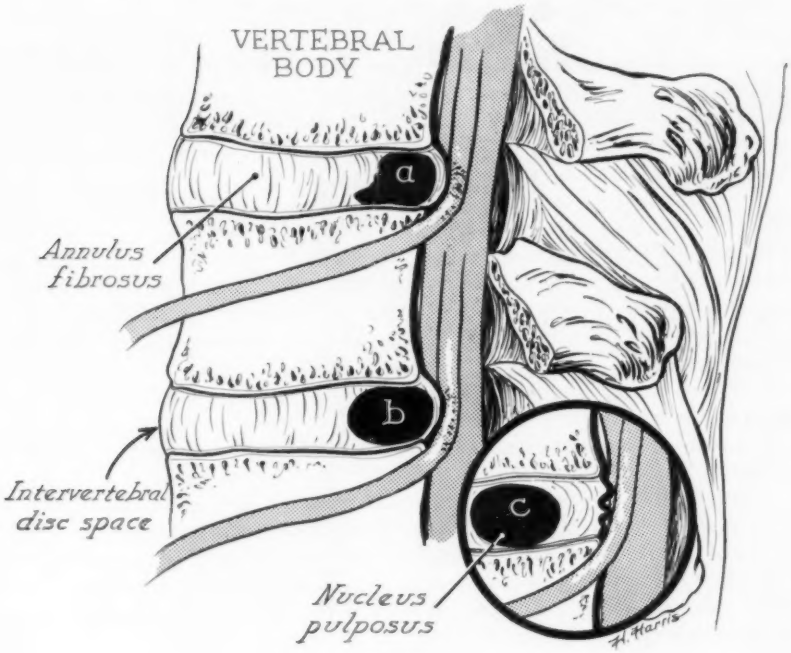

FIG. 4

Schematic drawing showing two pathological conditions of the disc found at operation: *a*, hard cartilaginous fragment wedged in the interspace; *b*, protrusion of "slipping disc"; *c*, "slipping disc" reduced and redundant annulus.

patients. The shortest period of time in which these complications occurred following satisfactory manipulation was three months and the longest period was eight years. Two were private patients, with injury occurring eight years and ten months, respectively, following treatment; these were successfully subjected to remanipulation. The remaining six were industrial patients; two of these were unsuccessfully manipulated, one was treated by laminectomy; the remainder were treated palliatively. All of the industrial cases resulted in measurable permanent disability awards and were classified as delayed failures.

2. The possiblity of fracture of the femur by too vigorous or by careless leverage during the manipulation has been considered. It is advisable to distribute the force by pressure over the posterior part of the trochanter and the ilium when manipulation is done. Fortunately, we have not experienced this possible complication.

3. In no patient in this series have symptoms been aggravated by the manipulation, and no motor weakness, paralysis, or complication of the bladder or rectal sphincter has occurred.

Further Treatment of Manipulative Failures

Whenever possible the persistence of complaints and objective findings after failure of manipulation resulted in a prompt recommendation of surgical intervention. In the present series, this was usually performed by a neurosurgical consultant, for it is our belief that they are better qualified. The procedure consisted in an interlaminar exploration with removal of a minimum of bony tissue. Primary fusion was not done except in those patients in whom instability was clearly demonstrated at the time of operation or in whom roentgenograms disclosed sufficient changes to render the back vulnerable to further disability. It is interesting to note that in the patients previously treated by manipu-

lation, who subsequently came to surgery, the myelograms were positive in all but one. In this patient a large disc was disclosed at operation. A short caudal sac was the probable explanation for the negative myelogram. There were two false positive myelograms. In these patients, operation resulted in an immediate postoperative relief of symptoms. When one patient was re-examined six months later, he had no subjective complaints, had a negative objective examination, and had returned to cowpunching. The other patient recently underwent a spine fusion.

Operative Findings

In the fifty-six patients in this series (27 per cent.) in whom the results were classified either as immediate or delayed failures, an interlaminar exploration was done. At the time of surgery, we were able to demonstrate a preponderence of three distinct types of pathological discs, which we believed may have accounted in a large measure for the failure of the manipulation:

1. An intact or a redundant annulus with protrusion of a hard cartilaginous fragment firmly locked in the interspace (Fig. 4, *a*);

2. A rupture of the annulus with a relatively large amount of the nucleus free in the spinal canal;

3. A degenerated nucleus with a redundant annulus, allowing increased mobility of the central mass (nucleus) similar to fluid movement in an elastic membrane under varying degrees and locations of pressure. (We were able to demonstrate on the operating table the ease with which this type of protrusion could be reduced and reproduced (Fig. 4, *b* and *c*). Manifestly manipulation is insufficient in such cases, and the "slipping disc" probably accounted for some of the delayed failures.)

END-RESULT STUDIES

1. The patients were divided into two groups, private and industrial.

2. The present status of the private patient was determined by personal interrogation and a comprehensive questionnaire.

3. The status of the industrial patient was analyzed by a review of the insurance carriers' records.

4. Analysis of age, sex, type of trauma, radiation of pain, duration of symptoms prior to manipulation, period of disability, and permanent disability was made on a data sheet.

5. Comparison of recovery and permanent disability factors between patients subjected to manipulation and operation was made.

6. The recovery rate between private and industrial patients was compared.

7. The percentage of recurrences after initial relief, necessitating further treatment, was determined.

Criteria for Classification of End Results

1. *Excellent:* Completely relieved, no activity restriction, no objective findings;

2. *Good:* Occasional back or extremity pain but no restriction in physical activity;

3. *Fair:* Variable transient non-disabling attacks of back or extremity pain which can be partly relieved by brace support and which does not prevent continuation of work (inability to do heavy lifting and reluctance on the part of the patient to accept further operative or non-operative treatment renders the result passable but not satisfactory);

4. *Immediate failures:* All patients who failed to respond after a maximum of two manipulations during the single hospitalization.

5. *Delayed failures:* Patients showing temporary recovery with recurrences which required further manipulation or subsequent laminectomy.

A total of 205 cases were analyzed, of which seventy-two were private and 133 were industrial. The percentage of satisfactory results in the private patients was 64 per cent.

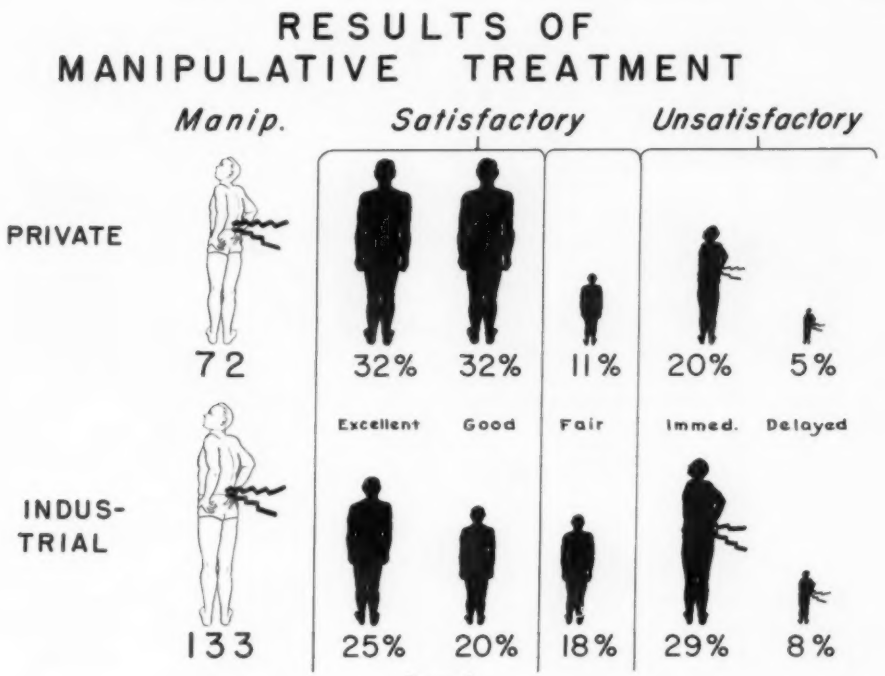

CHART I

This was divided into 32 per cent. *excellent* results and 32 per cent. *good* results. In this group, 11 per cent. were classified *fair*. *Immediate failures* resulted in 20 per cent. and *delayed failures* in 5 per cent.

The percentage of satisfactory results in the industrial patients was 45 per cent.; this was divided into 25 per cent. *excellent* results and 20 per cent. *good* results. In this group 18 per cent. of the results were classified *fair*. *Immediate failure* resulted in 29 per cent. and *delayed failure* in 8 per cent. (Chart I). The average period of follow-up was 22.8 months; the shortest being six months and the longest being ten years. There were 184 men and twenty-one women at the inception of treatment. Their average age was 39.8 years, the youngest being sixteen and the oldest sixty-five (Charts II and III).

Clinical Data

1. *Initial symptoms:* The inciting factor in practically all of the patients was relatively minor. Sixteen patients (7.8 per cent.) had no history of specific injury or sudden onset. Many patients' symptoms came on during a coordinated lift of various weights. Some had had a momentary twist or loss of balance in the flexed position or when climbing or walking. Falls on the buttocks were frequent.

2. *Pain:* Seven patients (3.4 per cent.) had no complaint of backache and in eleven, (5.3 per cent.) radiation of pain was absent. However, all had either backache, radiation of pain, or both.

3. *Objective Findings:*

a. Forward bending, usually with a flattening of the lumbar arc and reproduction of sciatic radiation, was limited in 152 patients (74 per cent.).

b. Positive straight-leg-raising (as well as Lasègue and Kernig signs) were present in 146 cases (71 per cent.).

c. Measurable atrophy of the thigh or the calf on the involved side was found in seventy patients (34 per cent.).

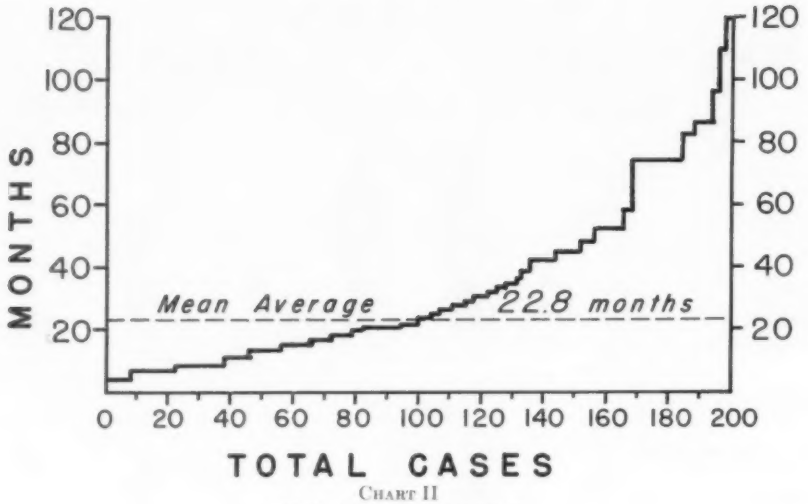

CHART II
Period of follow-up in months.

d. Demonstrable sensory changes of a persistent character, not including transient or recurrent hyperalgesia or hypo-algesia and most frequently involving the fifth lumbar and first sacral distribution, were noted in fifty-four patients (26 per cent.).

e. Minor motor weaknesses were noted in fourteen (6.8 per cent.) and usually involved the toe, ankle, and foot extensors. Weakness of the extensor hallucis longus was a fairly common diagnostic finding and was not included in this tabulation. Any patient with marked motor signs was primarily excluded from this treatment.

f. Asymmetry of the Achilles-tendon reflex or the patellar reflex or both were found in 109 patients (53 per cent.). Possible alterations in volume, if equal, were not listed.

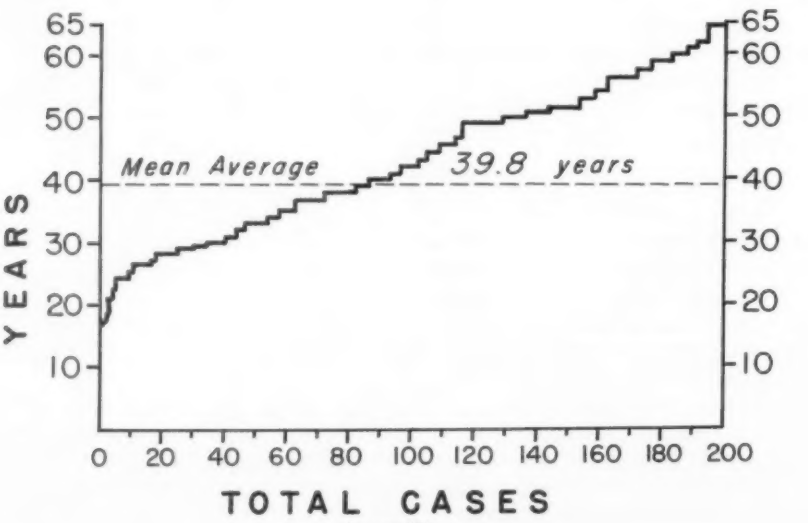

CHART III
Age distribution of 200 patients.

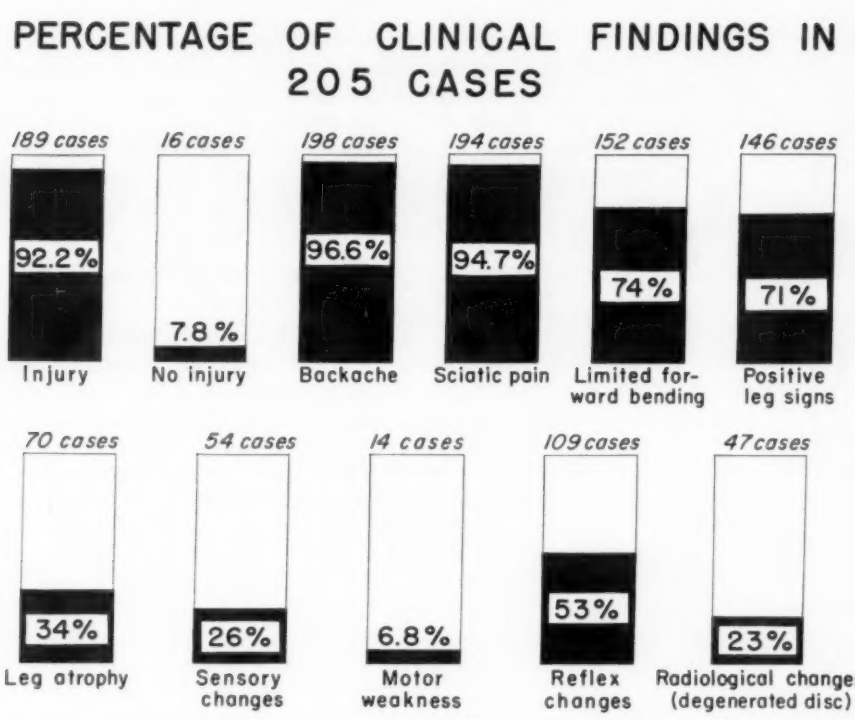

CHART IV

g. There were definite roentgenographic findings of degenerative disc changes in the involved level of the lumbar spine at the time of initial examination in forty-seven patients (23 per cent.) (Chart IV).

Comparison of End Results of Private and Industrial Laminectomies

A total of fifty-six laminectomies (27 per cent.) in seventeen private patients and thirty-nine industrial patients were done. Spine fusion was an additional procedure in seven industrial patients (18 per cent.) and in one private patient (5 per cent.).

By the use of the same clinical critieria for end-result evaluation, ten laminectomies in private patients (58 per cent.) resulted satisfactorily. However, only four patients (23 per cent.) were completely relieved (Chart V). The results in the *fair* (passable but not satisfactory) group draw attention to the question of whether or not the disc is the sole factor in this syndrome.

All of the industrial patients in whom fusion was done received some permanent disability rating, the lowest being 8.5 per cent. and the highest 60 per cent., with an average of 30.5 per cent. In those in whom simple laminectomies had been done, permanent disability ratings or a cash settlement was made for twelve patients for whom the facts were available. Seven patients had completely recovered without measurable permanent disability. In thirteen, the final result was not determined because of a lack of final statistical data. The results in the thirteen had been classed as *good* in eight and *fair* to *poor* in five. However, it can be assumed that all will receive some permanent disability rating. In the nineteen patients previously rated, the average permanent disability rating was 39.7 per cent. and the average cash settlement was $4,728.00. Of the ninety-four industrial patients treated non-operatively, in whom manipulation was done, twenty-two received a

permanent disability rating or a cash settlement. Seventeen patients were given a cash settlement, the lowest being $250.00 and the highest $4,000.00, with an average of $2,156.00. The five permanent disability ratings which were awarded were 73.25 per cent., 47 per cent., 47.75 per cent., 55 per cent., and 37 per cent.

In several of these patients, treated by manipulation and operation, the results according to our clinical criteria would have been classified as *good* but, because of monetary complications, the results were classed as *unsatisfactory*. Thus the marked discrepancy between the private and the industrial patient is partly explained.

Comparison of Medicolegal Permanent Disability Rating between Manipulative and Operative Cases

Although there has been no intention of attempting to decide the relative merits of the manipulative and surgical treatment of this syndrome, certain statistics are evident. These warrant a closer analysis. The operative cases were confined to the manipulative failures. This does not, however, invalidate an estimation of the end results as no added complications were introduced by the conservative treatment; no specific difficulties were encountered at operation which might place them in a different category from the average cross section of such cases treated primarily by surgical means. The only variable was a relatively short delay in the surgical attack prior to the decision of failure of conservative treatment. It is our impression, therefore, that the following statistics bear more than a coincidental relationship. This rather small sampling process creates, at least, a prognostic index, and reminds us again that the surgical end results are not uniformly of a quality to make operation a primary procedure of choice. These findings seem to be sustained by the survey, not alone from the medical standpoint but also from the financial one, and represent the ultimate cost to the average purchaser of compensation insurance in which most of us are interested, directly or indirectly, knowingly or unknowingly.

RESULTS OF LAMINECTOMIES PERFORMED ON MANIPULATIVE FAILURES.

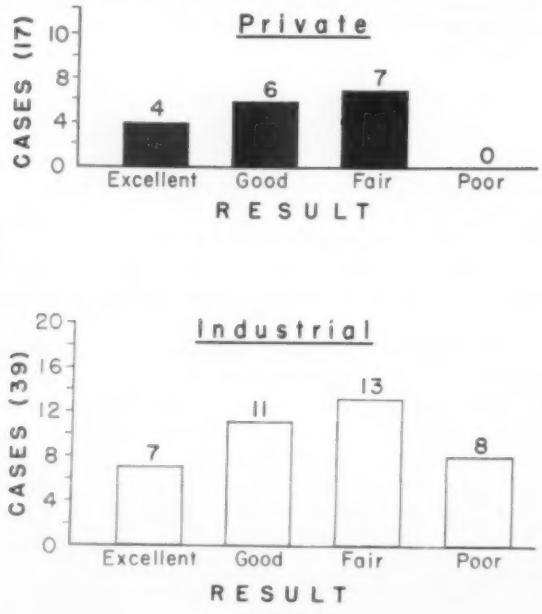

CHART V

In the patients treated by manipulation, twenty-two (23 per cent.) of the group, judged to have satisfactory or fair results, received permanent disability ratings or the cash equivalent which averaged $2,156.00.

In the thirty-nine patients in whom laminectomy was performed, with or without spine fusion, only seven (18 per cent.) recovered without measurable permanent disability. The others (82 per cent.) either had received or would receive some permanent disability award. In those available for study, the average was $4,728.00 — over twice that for the patients treated by manipulation (Chart VI).

Comparison between Cases Treated by Manipulation and Operation in Private Patients

There were forty-six patients with satisfactory results in the series treated by manipulation; of the satisfactory results 32 per cent. were *excellent*, 32 per cent. were *good*, and 11 per cent. were *fair*. In ten private patients in whom laminectomy had been done, the results fell in the satisfactory category, but 23 per cent. of these were classed as *excellent;* 35 per cent. were *good*, and 42 per cent. were *fair*. The evidence would seem to favor manipulative therapy (Chart VII).

DISCUSSION

There were 285 patients treated by this particular regimen of conservative treatment of a lumbar intervertebral disc syndrome. Patients for whom follow-up records were insufficient to answer the cardinal questions of the survey were discarded; 205 were available for final analysis.

The results obtained are based upon a particular regimen of conservative treatment which was followed uniformly for all patients. The manipulation was of a specific type, but it constituted only one phase of the therapy. We believe all phases are important in accomplishing the end

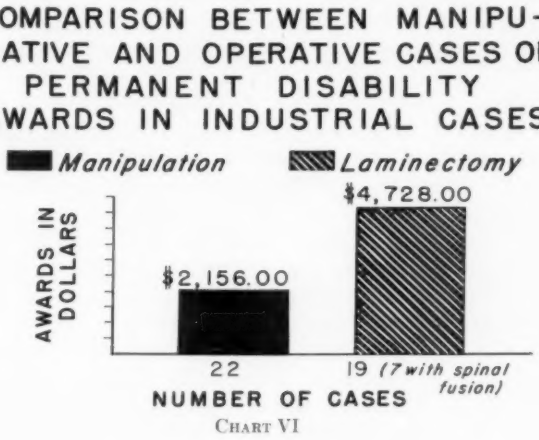

CHART VI

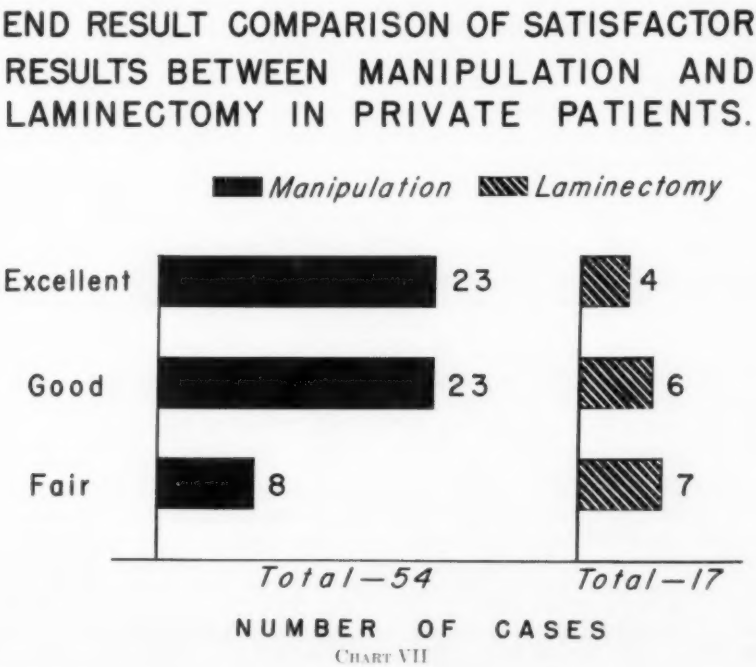

CHART VII

results obtained in this series. Whether other types of manipulation or variations in the regimen would result more favorably or unfavorably we are not prepared to state. It seemed important to reduce the manipulation to its simplest form; this best lent itself to analysis. The question has been asked repeatedly why anaesthesia was used in the manipulation. In our opinion, this offers optimum results and maximum safety.

With the patient completely relaxed, he can be immobilized easily in the desired position. The surgeon does not find it necessary to combat the patient's reflex muscle response at the same time he considers the amount of force he is using to perform the manipulation. It is recommended that the manipulation be performed slowly and evenly, with gradually increasing steady pressure until the end of the arc of motion has been reached; this pressure is then held for a few seconds. One complete arc of motion on each side seems to be all that is necessary. The following of these general principles should reduce the considered risk of complications to a minimum.

CONCLUSIONS

1. A conservative regimen which includes manipulative treatment of lower lumbar intervertebral disc syndrome under anaesthesia eventuates in a sufficiently high percentage of satisfactory results to warrant its use as an essential part of conservative therapy.

2. Treatment by manipulation should be given precedence over surgical intervention, except in those cases in which there is a definite contra-indication.

3. Satisfactory results, if obtainable, are to be expected after one or, at the most, two manipulations; repeated manipulation is not justified. Successful treatment is predicated upon a prompt loss of sciatic pain.

4. Failure to respond to an organized regimen of conservative treatment, including manipulation under anaesthesia, warrants the recommendation for prompt surgical intervention, provided the incapacity is sufficiently pronounced.

5. A certain percentage of cases are not amenable to manipulation, but premanipulation differentiation is impossible in the light of our present knowledge.

6. This series reveals a higher percentage of complete symptomatic relief following manipulation and its accompanying regimen than that following surgery, with a lesser amount of permanent disability in those cases in which residual disability persists.

7. Substantiating the premise that disc herniation is on the basis of disc disease, 23 per cent. of the patients in this series showed demonstrable roentgenographic disc changes prior to the beginning of treatment.

8. The apparent discrepancies in end results between the private and the industrial patient can be explained by the monetary factor and the larger percentage of the latter patients engaged in heavy labor.

NOTE: Our sincere thanks is expressed to Dr. J. H. Limbach, Medical Director of the State Compensation Insurance Fund, and to various insurance carriers whose earnest cooperation made this analysis possible.

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(*Continued on page 984*)

BONE AND JOINT TUBERCULOSIS AND ITS TREATMENT *

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From Jesus Hospital, Rio de Janeiro

Tuberculosis in Brazil is still epidemic, and in the city of Rio de Janeiro alone there are more than 100,000 cases of pulmonary tuberculosis. Although the mortality rate has dropped rapidly because of the modern therapeutic arsenal, it is still at the high level of approximately 200 to each 100,000 inhabitants.

Chart I, based on the official figures of the Health Department, shows an extremely high mortality rate from tuberculosis during the years from 1920 to 1950; it also shows the gradual drop from 600 cases per 100,000 of population in 1920 to about 300 cases per 100,000 in 1950. The advent of streptomycin and isonicotinic acid hydrazide, the opening

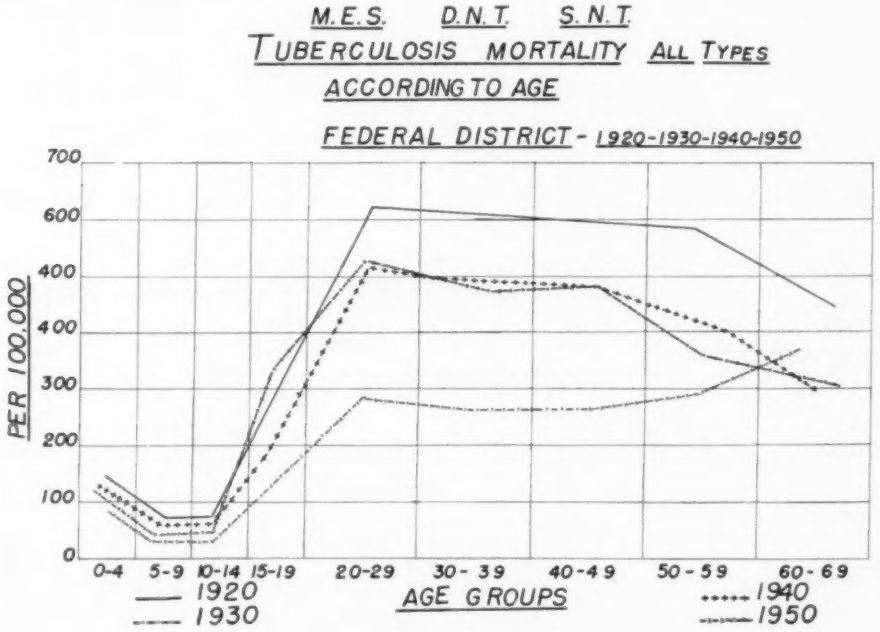

CHART I

of more hospitals, and the many improved diagnostic resources are notably accelerating the fall in the rate of mortality from tuberculosis. At the present moment the situation in Brazil can be compared to the condition which prevailed in the United States at the turn of the century. Other evidence of improvement is seen in the comparison between the mortality from tuberculosis and from heart disease from 1910 to 1952. In Chart III, the line representing tuberculosis crosses that representing heart disease at 1949. Mortality from tuberculosis is on a downward trend, while mortality from heart disease is on an upward trend. The spectacular drop in the mortality from tuberculosis in the United States, as in many other countries, is the direct consequence of the ever-increasing higher

*Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 26, 1954.

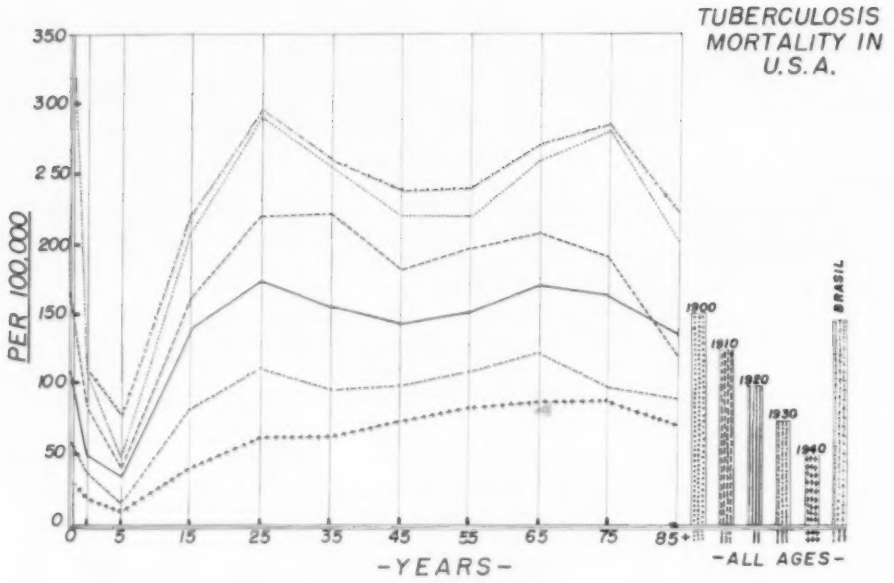

CHART II

Comparison of mortality rates from tuberculosis in the United States and Rio de Janeiro at the present time.

CHART III

INFANTILE MORTALITY IN RIO DE JANEIRO 0–1 YEAR	1949	1950	1951
ALL CAUSES	5444	5814	5973
GASTRO-INTESTINAL SYNDROMES	2036	2015	1950
PULMONARY DISEASES	1148	1190	1031
PREMATURES- CONGENITAL DEBILITY -	1009	705	913
GRIPPE	239	265	236
CHILD-BIRTH	?	216	230
TUBERCULOSIS (ALL TYPES)	68	66	57

TUBERCULOSIS

TABLE I

COMPARATIVE GRAPHICS OF SKELETAL TUBERCULOSIS AND TUBERCULOUS MENINGITIS MORTALITY IN RIO DE JANEIRO

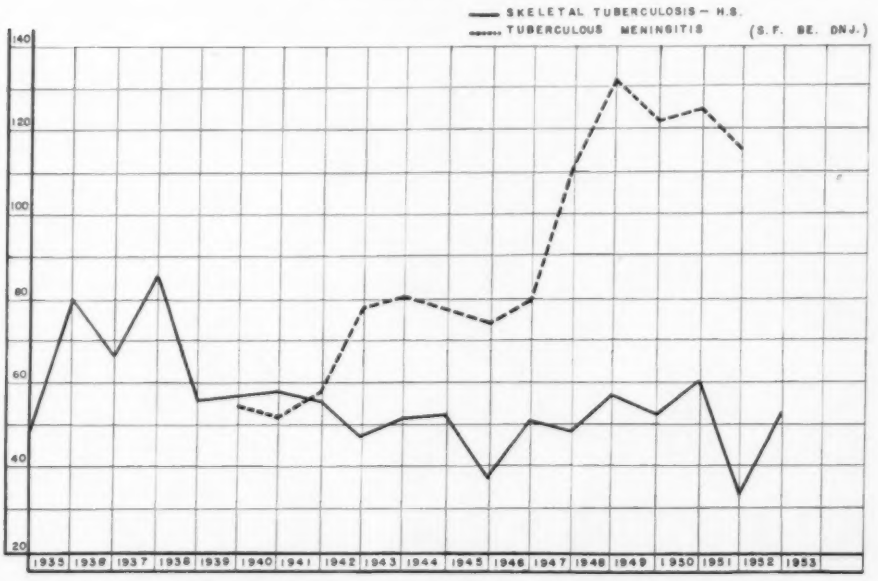

CHART IV

TABLE II
ROENTGENOGRAPHIC SURVEY

Age	Slums			Proletarian Houses		
	No. of Cases	Tubercular	Per cent.	No. of Cases	Tubercular	Per cent.
Less than 1 year	63	4	6.3	19	0	0
1 to 6 years	346	48	13.8	136	7	5.1
7 to 14 years	428	13	3.0	172	4	2.3
Total	837	65	7.8	327	11	3.3

standards of living and modern hygienic precepts. Infant mortality before the age of one year in Rio de Janeiro, however, is still extremely high. The mortality from all types of tuberculosis has not yet been properly estimated there, because the great majority of tuberculosis cases are recorded as gastro-enteritis or as acute bronchitis. In Table I is shown the rate of mortality from all causes during 1949, 1950, and 1951. Chart IV, in which the mortality rate from skeletal tuberculosis and tuberculous meningitis is given, is highly significant of the prevailing conditions in Rio de Janeiro.

In the slums of Rio, a striking relationship is found between the low standard of living and the incidence of tuberculosis. In the so-called Favellas (slums) the Government is building better types of residences, and the Proletarian Park is separated from the Favella by a narrow alley. The people living in houses of the Proletarian Park have a trifle better standard of living. They have more comfortable houses than those across the alley.

FIG. 1

Calcified mesenteric lymph nodes of a probable intestinal primary complex.

The results of a roentgenographic survey (Table II) reflect a marked difference in the incidence of tuberculosis between people living in the same surroundings but enjoying better conditions. In the Favellas, of 839 persons subjected to study by x-ray, sixty-five (7.8 per cent.) were found to have tuberculosis, while in the houses of Proletarian Park, of 327 persons subjected to study by x-ray, only eleven (3.4 per cent.) were found to be infected.

The incidence of bone and joint tuberculosis in Brazil is in direct relationship to the incidence of pulmonary disease; the infecting organism is the human bacillus, the bovine type being unknown. Not one proved case of the bovine type of human tuberculosis has ever passed through Jesus Hospital or the Central Laboratory for Tuberculosis. (The latter is under the capable direction of Dr. Milton Fontes Magarão.)

Tuberculosis in adults or in children, whether pulmonary or skeletal, is always one and the same problem. There is always a direct relationship regarding its origin, evolution, clinical

FIG. 3

Primary complex complicated by tuberculous meningitis, without latent period intervening.

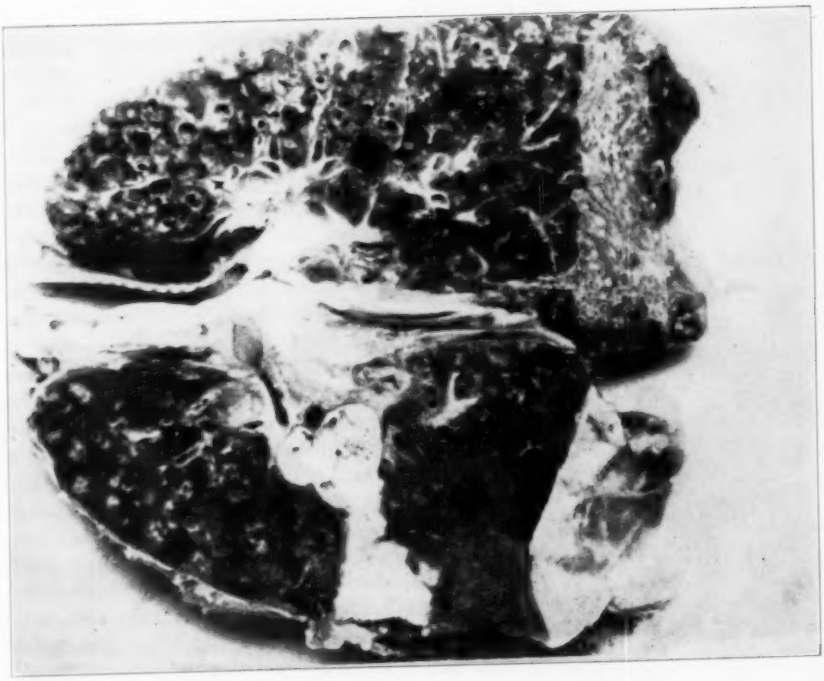

FIG. 2

Primary complex complicated by miliary tuberculosis.

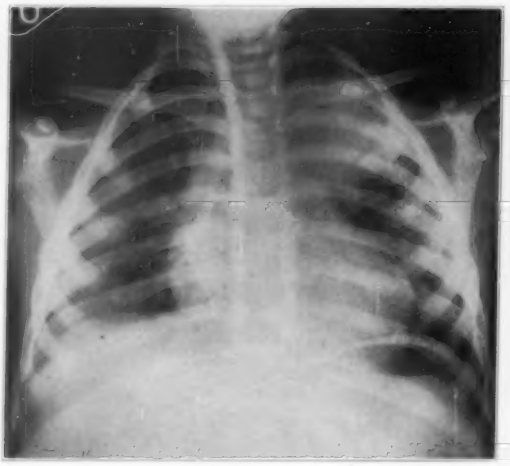

FIG. 4-A

FIG. 4-B

Primary complex followed without a latent period by knee tuberculosis. There is a small lesion on the outer condyle of the femur.

manifestations, and curability to the general biological phenomenon of the tuberculous allergy.

The general concept of tuberculosis was established by Ranke after study of its pulmonary localization. By x-ray and microscopic examination of the anatomical structure of the lungs, where the disease practically always begins, an easy field for following the different reactions provoked by the very first contact of the tubercle bacillus with the uninfected organism was afforded. The concept of Ranke establishing the evolution of tuberculosis from its onset to its ultimate stages is divided into three periods. The first period is that of the primary complex; the second is that of hematogenous dissemination; and the third is that of organized lesions. This concept is obviously schematic; however, it is a trustworthy and useful guide. Skeletal tuberculosis is always caused by a secondary hematogenous dissemination from a pulmonary lesion. In fact, the conditions for primary infection originating in a joint do not exist. The intestinal primary complex seems to be rare; only one suspected case appears in our records (Fig. 1).

FIG. 5-A

The primary complex is the clinical expression of the Koch phenomenon, and its evolution depends upon various factors, biological or constitutional in nature, which are called upon to play a part at its inception. The primary complex does not develop in a state of *total anergy*. It is always accompanied by focal reactions, because the host, although uninfected, does not stay inactive during the incubation period. It reacts promptly with exudative phenomena, which are sometimes very extensive. The primary complex, when

FIG. 5-B

Figs. 5-A, 5-B, and 5-C: Typical tertiary lesion of the caseous productive type of the left knee, dating from 1945, gave secondary "bud" to the left hip joint in March 1951, followed two months later by fatal miliary generalization.

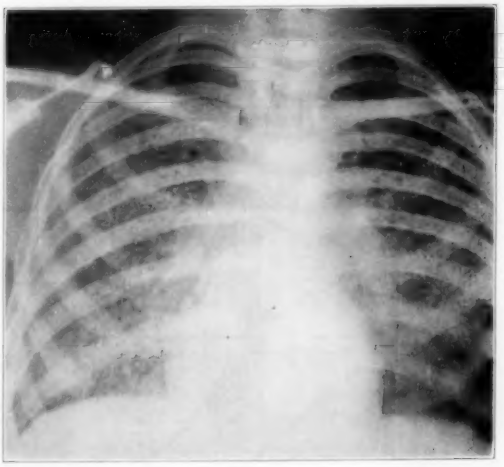

FIG. 5-C

uncomplicated, will heal and will leave the organism in a particularly immune condition in which it is capable of violent reactions in the case of supervening exogenous or endogenous attack by the Koch bacillus. In some cases, when the organism is unable to check the infection at its inception, the primary complex may be followed by immediate serious complications leading to primary miliary tuberculous meningitis or primary phthisis, which ordinarily terminate fatally.

It seems, in countries in which tuberculosis is epidemic, that the complicated primary complex is followed not only by miliary tuberculosis or tuberculous meningitis but also by other disseminations without any latent period intervening. Quite frequently these involve the skeleton.

This seems to be the only possible explanation for the astonishingly high percentage of skeletal lesions seen in patients before one year of age, as registered in our records. Assuming that the results from the tuberculin test change from negative to positive at an early date, shortly after birth, among underprivileged people suffering from epidemic tuberculosis, the distribution of our cases in Wallgren's scheme (Fig. 6) is most interesting. Wallgren has attempted to establish a certain schedule for the appearance of specific tuberculous conditions after the incubation period. The risk of falling ill with a particular type of tuberculosis, after its proper period has elapsed, drops very rapidly indeed. The first stage, reached about six weeks after infection, is that of the primary complex and related symptoms. The second stage, which lasts for about three months and follows

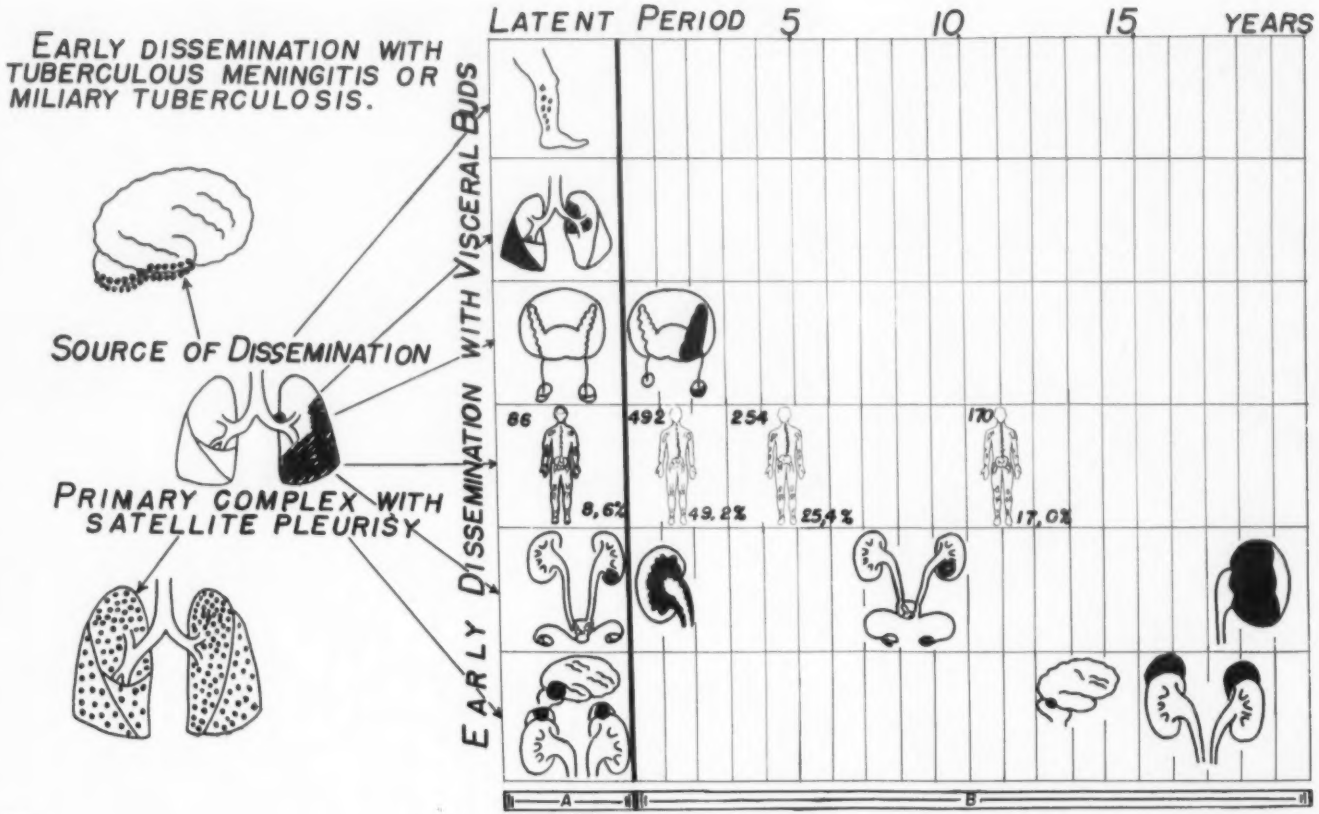

FIG. 6

Wallgren's scheme of the latent period of pulmonary tuberculosis with early hematogenous dissemination.

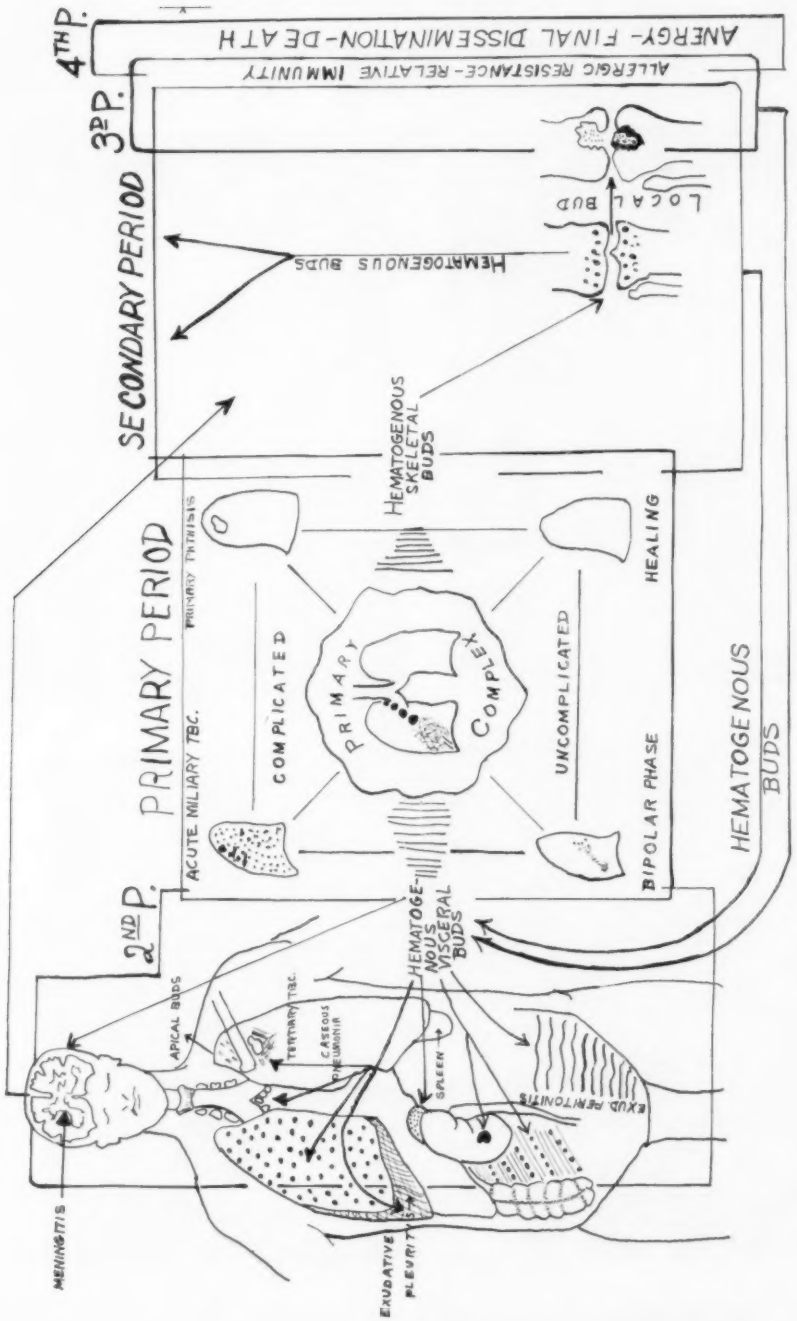

Fig. 7

Schematic representation of the combined theories of Ranke and Redeker.

immediately after the first, is the stage of primary miliary tuberculosis and tuberculous meningitis. It is in this stage that a great number of our patients with skeletal disease, particularly those with tuberculosis of the spine, are first seen. The third stage, that of pleuritic complications, lasts until the fourth month. Then finally comes the fourth stage, which lasts until the healing of the primary complex about the completion of the first

FIG. 8-A

FIG. 8-B

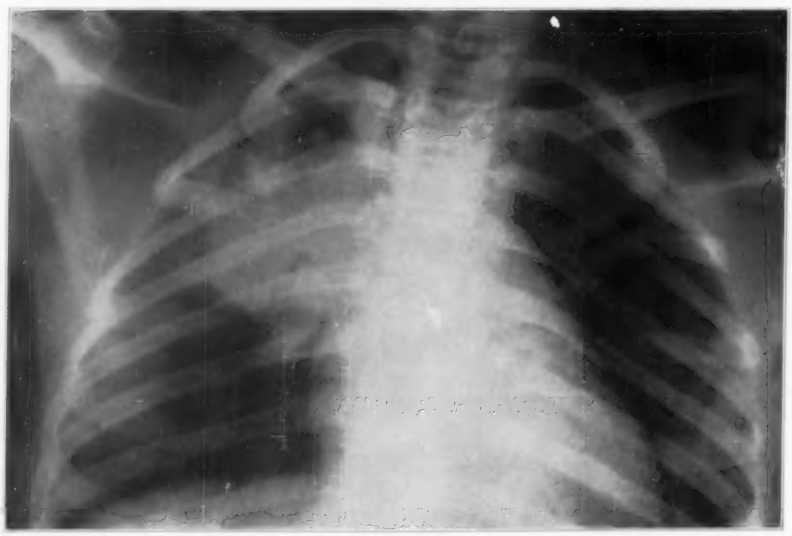

FIG. 8-C

Figs. 8-A, 8-B, and 8-C: Granular type of hip tuberculosis, apparently mild, in March 1941. In June 1941, a local flare-up bud with intense exudative phenomena occurred, followed three months later by caseous exudative pulmonary tuberculosis.

FIG. 9-A

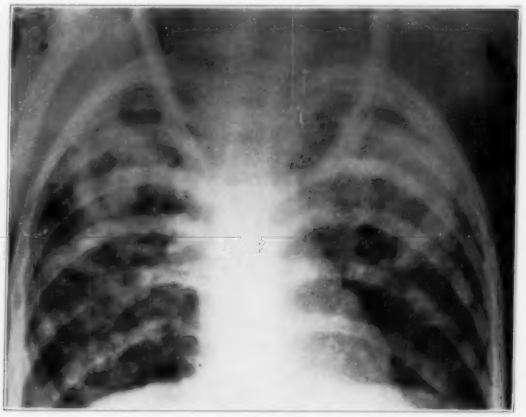

FIG. 9-B

Figs. 9-A and 9-B: Long-standing knee tuberculosis, which in spite of all care was complicated three years later by fatal productive miliary tuberculosis.

Fig. 10-A: Exudative elbow tuberculosis which is predominantly granular.

Fig. 10-B: Fibroproductive tuberculosis of the elbow.

FIG. 10-A

FIG. 10-B

year. This is considered the most dangerous stage from the standpoint of skeletal tuberculosis. The danger gradually declines until the third year; thereafter, the risk of osteo-articular tuberculosis becomes practically negligible.

The organism, sensitized by the primary infection (after precipitating all immunological reactions), is permanently alert against any other aggression, and reacts with hypersensitivity to the tuberculosis toxin. This is the second period, the period of secondary allergy of hypersensitivity. Disseminations to the visceral, skeletal, and nervous systems ordinarily occur in this period. The autopsy findings of Hübschmann and Randerath have shown that practically every bone is affected by hematogenous dissemination, and numerous bacillary emboli are found, particularly in the epiphyses of the long bones.

If the organism builds up enough resistance to overcome disease at this period, and ordinarily it does, the third period ensues. The third period is the period of the so-called

FIG. 10-C

FIG. 10-D

FIG. 10-E

Fig. 10-C: Ulcerocaseous tuberculosis of the knee.
Fig. 10-D: Predominantly caseous exudative tuberculosis of the knee. This is an extremely serious tumor-like form.
Fig. 10-E: Photograph of the knee shown in Fig. 10-D.

allergy of immunity. We would rather call this allergy of resistance because we do not like to talk of immunity in tuberculosis since such a thing does not exist. This is the period of localized lesions, which develop in the same manner as local tuberculosis, without provoking general manifestations.

The evolution of tuberculosis from the primary complex to its different periods is not a continuous process, but it evolves by spells with intermittent quiet intervals, in which the *Mycobacterium tuberculosis* is latent, but virulent in a lymph node, in a fibrous lesion, or in a calcified lesion. Redeker's concept of the "bud" or early infiltrate completes the theory of Ranke and explains in full the mechanism of the disseminations of the second period. The observation of clinical records of patients with skeletal tuberculosis affords conclusive evidence of the truth of the combined theories of Ranke and Redeker. An affected joint in which disease originated from a more or less distant dissemination of a pulmonary lesion shows all the characteristics of the second period. After a variable period of time, in relation to the behavior of the defending organism and the attacking bacillus, the lesion gradually becomes chronic (the tertiary period). Any established tertiary lesion in a joint or in any other organ, in apparent quietude, can suddenly become active again, and start a local bud, a flare-up of local symptoms, or give place to a new dissemination.

A marked instability is the only characteristic of any period of the tuberculous infection, and the three different periods are nothing but links of the same chain. Any alteration in the immunological resistance of an apparently stable lesion of the third period, such as

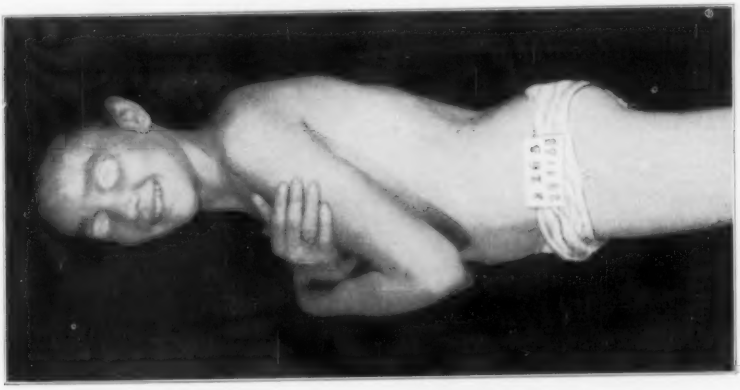

FIG. 11-C

FIG. 11-B

FIG. 11-A

In a patient with tuberculosis of the spine, the spine had been fused at the age of four. The result ten years after the operation is shown.

FIG. 12-A

FIG. 12-B

FIG. 12-C

Figs. 12-A, 12-B, and 12-C: Hip fusion was done at the age of five. The result sixteen years after operation is shown.

that caused by trauma, intercurrent disease, endocrinological factors, or pregnancy can bring about a true regressive change from the allergy of resistance to the hyperergic state of the second period and start a new bud. The schematic representation of the combined doctrines of Ranke and Redeker (Figs. 8-A, 8-B, and 8-C) shows clearly the vicious circle of the tuberculous infection.

It is well known that tuberculosis does not develop by such a logical process, but this combination of theories has brought to light a great deal of truth from the disentanglement of confused evidence which existed prior to its formulation. The concept of local allergy, the concept of tissue allergy derived from the interesting experiments of Auer, and the fourth periods of Pagel and Ulrici are very important to the interpretation of particular phenomena recorded in clinical histories. The fourth periods of Pagel and Ulrici follow the ulcerocaseous forms of long-standing disease, which has consumed all of the defensive powers of the organism. The organism then returns to a final state of anergy.

FIG. 13-A

FIG. 13-B

Figs. 13-A, 13-B, and 13-C: Fusion was done on a tuberculous knee with marked destruction of the joint at the age of four. The result ten years after operation is shown.

FIG. 13-C

When the last immunological barriers have been overcome, the victim dies from a productive type of late miliary tuberculosis which is quite often found in the aged sufferer with a long-standing tuberculous process.

PATHOLOGY

The pathology of osteo-articular tuberculosis is directly related to the general problem of tuberculous infection; the same types of disease are observed in the joints as in the lungs or in any other organ. It is a well known fact that the *Mycobacterium tuberculosis* has a striking preference for localization in the vertebrae and epiphyses of the long bones. In our records, diaphyseal localization is extremely rare, only one or two proved cases being recorded. Pure synovial involvement cannot, of course, be denied, but we believe it to be rare; and, since tuberculous synovitis has been practically always followed by joint lesions, any controversy is deprived of real interest. The fact that all epiphyseal lesions are accompanied by synovial reaction does not mean that the synovial membrane is specifically affected. The synovial membrane is very much like the pleura and reacts to the specific inflammatory process in the osseous component of the joint by an unspecific exudation. The different types of osteo-articular tuberculosis, according to Urbach's scheme, are regulated by the relative amount of antigens and antibodies in each case, with the circulatory phenomena playing an important part. There are mainly three different types of osteo-articular tuberculosis —

FIG. 14-A

FIG. 14-B

Figs. 14-A and 14-B: Patient had tuberculous osteo-arthritis of the subtalar joint. Cure was obtained by conservative means. The patient is still under observation.

FIG. 15

Fig. 15: Patient had had tuberculosis of the hip from the time she was three years old. She had been treated by conservative means for fifteen years. At the end of that time there was apparent fusion of the joint. However, at eighteen she suffered an acute relapse. There was much motion in the joint, and acute evolutive lesions were found at operation. Arthrodesis was done and fusion of the joint and a permanent cure resulted.

the granular, the exudative, and the caseous. Although a knowledge of these different types is very important, it is sometimes difficult to establish them accurately from study of the roentgenogram. They seldom exist exclusively, since they are always found mixed in the same joint. Thus, in order to be more accurate, one should speak of a type as predominantly granular, exudative, or caseous.

Since 1935, over 1,000 cases of osteo-articular tuberculosis have been admitted to Jesus Hospital, and the records of these cases have been reviewed for the purposes of this paper (Table III). The age of onset is sometimes very difficult to determine, because quite frequently the first symptoms observed by the patient's parents were swelling of the joint or deformity. This was particularly true in patients with spinal disease. The ages shown, however, are considered to be the maximum for the occurrence of the disease.

TREATMENT

Surgery at Jesus Hospital is considered the only means of coping with the ever-increasing number of cases of skeletal tuberculosis. Our early experience has been so satisfactory that all patients who meet certain requirements of general condition and stage of the local lesion are operated upon, regardless of age. Thus spines, hips, and knees have

TABLE III

SUMMARY OF 1,000 CASES

	No. of Cases	Per cent.
Spine	555	55
Less than one year	63	6.3
From one to three years	320	32.0
From four to six years	103	10.3
Above six years	58	5.8
Hip	198	19.8
Less than one year	10	1.0
From one to three years	76	7.6
From four to six years	68	6.8
Above six years	44	4.4
Sacro-iliac joint	1	0.1
Knee	142	14.2
Less than one year	7	0.7
From one to three years	54	5.4
From four to six years	44	4.4
Above six years	37	3.7
Ankle	13	1.3
From one to three years	9	0.9
From four to six years	1	0.1
Above six years	3	0.3
Tarsal	26	2.6
From one to three years	8	0.8
From four to six years	7	0.7
Above six years	11	1.1
Shoulder	8	0.8
Less than one year	1	0.1
From one to three years	3	0.3
From four to six years	1	0.1
Above six years	3	0.3
Elbow	18	1.8
Less than one year	3	0.3
From one to three years	9	0.9
From four to six years	3	0.3
Above six years	3	0.3
Wrist	1	0.1
Spine and Hip	13	1.3
Spine and Knee	8	0.8
Less Important Associations	17	1.7

been fused in many patients before the age of five. Figures 12-A through 14-B show typical results of more than ten years' duration in patients subjected to fusion before five years of age.

We soon became aware of the intricate and complex problem of tuberculous allergy and have acquired greater knowledge of it from the interpretation of the different laboratory tests and clinical data, with consequent improvement in our results. It is not suggested that immediate operation is the answer in every patient. Far from it. We have operated upon numerous patients a few weeks after admission; some, six months after; some, one year after; and we have had patients for over 3,000 days in our service who have died of tuberculosis, without being brought to surgery.

The general principles of treatment apply equally to children or adults. There is not much difference between infantile and adult osteo-articular tuberculosis. The disease depends more on the development of allergic conditions than on the age of the patient. Infantile tuberculosis is obviously closer to the primary period of infection, while in the

adult the disease is quite often a form prolonged from childhood and is closer to that of the tertiary period and shows, therefore, more tendency to spontaneous healing by fibrosis. The only real difference lies in the type of arthrodesis, which in the case of children must, of course, comply with the development of the skeleton. The routine treatment of joint tuberculosis is accomplished in two stages. The first is general care and plaster immobilization and the second, whenever possible, is early fusion of the joint in order to attain a rapid and a permanent cure. By means of surgical treatment, the long periods of immobilization, with the attendant atrophy of the limbs, marked shortening of the limbs, or epiphyseal disturbances, are avoided. We have found that some cases of pure synovial involvement or mild osteo-articular lesions may heal by conservative methods under ideal conditions.

The results of treatment of osteo-articular tuberculosis from conservative methods are of poor quality, resulting in a marked fibrous rigidity of the joint, with extensive erosions of the articular surfaces. This spontaneous fibrosis results in a false and unstable cure, because numerous latent foci of virulent bacilli remain enclosed in the fibrous tissue and in the bony cavities, ever ready to spring out and to start active local phenomena or new buds. Thus there is a return to the dangerous secondary period of hyperergy subject to fatal complications, such as late productive miliary tuberculosis. Ordinary use of a joint aggravated by faulty anatomical conditions, intercurrent disease, humoral changes which are likely to occur in puberty or during pregnancy are some of the many causes which may break down the unstable equilibrium of the tuberculosis allergy and may turn apparent inactive foci into evolving lesions.

The permanent cure of tuberculous osteo-arthritis can only be obtained by a perfect bony ankylosis, brought about rapidly and securely by the different methods of arthrodesis based on sound anatomical and physiological principles, as proposed by Hibbs, Albee, and others since 1911.

CONDITIONS FOR OPERATION

Good general condition, prolonged apyrexia, roentgenographic evidence of focal stability or, better, of a lesion progressively improving, are reliable clinical signs favorable for surgery. The clinical findings must be confirmed by repeated blood counts, the last one of which should be done two or three days prior to the operation. The careful study of repeated hemograms is extremely important and has been our best guide in dealing with tuberculosis for the past fourteen years.

The hemoglobin and the red blood count must be normal or not too low. The important information, however, is derived from the white blood count. The fundamental works of Cunningham, Sabin, Wiseman and Doan, and Medlar have shown that the changes in the white blood count are of great significance, and that they constitute a sensitive indication in determining the evolution of the different stages of the tuberculous infection. The role of the lymphocytes, monocytes, and eosinophils in the defense mechanism has been established. Considerable emphasis is placed on the relation between monocytes and lymphocytes.

We have plainly confirmed that a high lymphocyte count and a low monocyte count is an indication of high resistance of the host, which places the patient in a favorable allergic condition, and, on the contrary, a low lymphocyte and a high monocyte count is a sure sign of low resistance of the host, which consequently places him in an unfavorable allergic condition, and indicates the formation of a new bud and a return to the dangerous stage of hyperergy. We consider as a practical indicator that the lymphocyte-monocyte ratio, obtained by the division of the count of the lymphocytes by that of the monocytes, must have a count of five or better. The higher the ratio is above five, the better. We have observed that in practically every patient operated upon who had a lymphocyte-monocyte ratio below five, some complication, quite often serious and fatal, occurred. All

patients operated upon with a ratio above five did very well, and not a single one died of an early tuberculous complication, or any other complication. We believe the lymphocyte-monocyte ratio is so trustworthy that we do not dare to perform a biopsy puncture or to change the defective position of a joint when the blood count shows a lymphocyte-monocyte ratio below five. It must be clearly understood that all leukocytic alterations in the circulating blood supply nothing but clinical information. However, it is of considerable value in determining early any changes that may be occurring in the allergic condition of a patient with tuberculosis. This ratio is subject to constant variations due to the very unstable character of the tuberculous allergy. If the lymphocyte-monocyte ratio is high one week, and drops, for instance, during the next, we believe that something has happened to the tuberculous lesion, that a localized or a generalized bud has developed, and that the patient has returned or is about to return to the second stage of hyperergy. He most certainly should not be disturbed as it will prove to be hazardous.

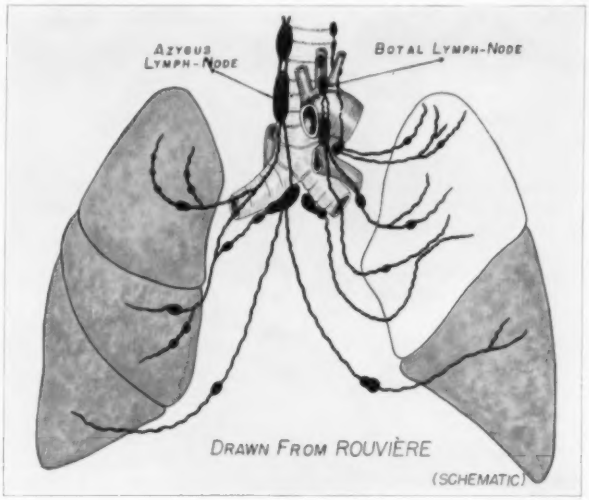

FIG. 16
Lymphatics of the lungs.

We have, countless times, observed the lymphocyte-monocyte ratio to be in striking disagreement with the sedimentation rate, which, in our opinion, does not have the value attributed to it by the majority of the specialists. Of course, the sedimentation rate has some prognostic value, but it is subject to so many variations, outside the evolution of the tuberculous process, that it is an unreliable test. We have operated upon many patients with an extremely high sedimentation rate, but with a very good lymphocyte-monocyte ratio and have not had any complications at all.

SKELETAL AND PULMONARY TUBERCULOSIS

The study of a series of chest roentgenograms in 500 cases of skeletal tuberculosis has disclosed interesting facts that call for further investigation.

Figure 16 is a comprehensive drawing showing the lymphatic pattern of the lungs. It shows that the lymphatic drainage of all three lobes of the right lung, and of the inferior lobe of the left lung, goes directly or by way of the ganglion group of the tracheal bifurcation, to the right paratracheal chain. The main lymph node of this chain, the azygos node, situated above the crossing of the azygos vein, is very important because it filters the lymphatics from three-fourths of both pulmonary fields, and is more frequently and with greater intensity affected by the tuberculous infection.

The lymphatics of the upper left lobe are tributaries of the anterior mediastinal and of the left paratracheal chains, along which are situated a large node, the botal node, and several less important small ones. The lymph flows readily into the subclavian vein.

The knowledge of the lymphatic patterns of the lung field is of considerable significance in the detection of the location of the primary infection. In primary infections of the right lung and of the lower lobe of the left lung, a much stronger barrier is found to the

TABLE IV

SITE OF LESION IN 500 CASES

	No. of Cases	Per cent.
Active lesion of the right lung	58	
Active lesion of the left lower lobe	3	
Active lesion of the left upper lobe	6	
Bilateral lesion	1	
Total active lesions	68	13.6
Residual lesion of the right lung	107	
Residual lesion of the left lower lobe	16	
Residual lesion of the left upper lobe	23	
Total residual lesions	146	29.2
Normal lungs	286	57.2
Less than one year	3	4.4
From one to three years	38	55.1
From four to six years	11	16.1
Above six years	7	10.2
Adult	1	
Not computed	8	
Associated skeletal lesions:		
Spine	30	44.1
Hip	1	1.4
Knee	3	4.4
Elbow	1	1.4

spreading of the tubercle bacillus. The infections starting in the upper left lobe are opposed by a much weaker barrier, and disseminations are more prone to occur. It has been our experience, at Jesus Hospital, that every primary infection of the upper left lobe should be watched very closely.

Our routine procedure is to examine the chest of every patient roentgenographically upon admission to the Hospital. The chest and the joints of all patients with tuberculosis are examined frequently by means of roentgenograms.

An analysis (Table IV) showing the distribution of the 500 cases according to age and the type of lesion is extremely interesting.

Our figures do not quite agree with reports on the same subject by Hecker and by Gonzales-Aguilar. It is evident that the coincidence of skeletal and pulmonary tuberculosis decreases with advancing age, and that in a great number of adolescents and adults foci of lung tuberculosis are metastases from a diseased joint or spine. The coincidence of identical types is rather unusual.

The high percentage of 57.2 of normal lungs in patients with epidemic tuberculosis is rather paradoxical. We were surprised that very serious types of bone or joint tuberculosis were observed in practically all patients with normal lungs. It is reasonable to admit that in such cases the infecting bacilli just passed through the lungs almost unchecked because of the particular lack of resistance on the part of the infected host, causing an immediate general dissemination with skeletal localization. We believe that this observation deserves more careful investigation.

STREPTOMYCIN AND ISONICOTINIC ACID HYDRAZIDE IN SKELETAL TUBERCULOSIS

A discussion of the subject of the use of streptomycin, para-aminosalicylic acid, and isonicotinic acid hydrazide in the treatment of tuberculosis has been saved for the last. This entire paper has been written as though these drugs did not exist. This was done purposely because of the need to emphasize that everything which has been dealt with in the earlier portions of the paper is still true.

The use of streptomycin and isonicotinic acid hydrazide was begun as soon as these

Fig. 17-A

Fig. 17-B

Fig. 17-C

There is bilateral involvement of the lungs; botal and azygos lymph nodes are shown. Patient had tuberculosis of the lumbar spine which was cured by arthrodesis. Fig. 17-C made many years later shows calcification of botal and azygos nodes.

drugs became available. We use the same words of praise concerning the improvement in the general condition of the patient, his increase in weight, and the closing of discharging sinuses as other investigators have. The drugs are a great adjuvant in the treatment of skeletal tuberculosis; they are very good, but are, indeed, far from miraculous.

From our observation, we know that the new drugs alone offer no cure for tuberculosis. The time of observation of the results from treatment with these has been too short to allow talk of a cure of osteo-articular tuberculous lesions. Such a cure, when brought about by conservative methods, particularly in the spine or in weight-bearing joints, requires many years of careful observation. We have been accustomed to see so-called "cured cases" of tuberculous synovitis or mild osteo-arthritis do very well for ten or fifteen years; then all of a sudden, for some particular reason, a serious or even fatal relapse will occur in the same joint or elsewhere. We have at the present moment a few patients who have apparently been cured by means of streptomycin and para-aminosalicylic acid or isonicotinic acid hydrazide, with normal function of their joints. We consider them to be cured only for the present moment, and they have been warned to return to the hospital for periodic inspection.

In spite of the opinions of some phthisiologists gained from experimental work which seems to show more brilliant results from treatment with a combination of small doses of streptomycin, isonicotinic acid hydrazide, and para-aminosalicylic acid, we prefer a calmer and more moderate approach to the problem. We have been carrying out an experiment of sorts in which we have never used the drugs at the same time. We have used streptomycin and para-aminosalicylic acid alone, or isonicotinic acid hydrazide alone; and in some cases of long-standing disease, when failures have occurred with prior treatment with streptomycin and para-aminosalicylic acid, we have resorted to isonicotinic acid hydrazide.

We will try to analyze the action of the isonicotinic acid hydrazide directly on the *Mycobacterium tuberculosis* to discover what happens in the light of the biological phenomenon of tuberculous allergy. Isonicotinic acid hydrazide acts, contrary to the action of streptomycin and para-aminosalicylic acid, or of any other drug used in the treatment of tuberculosis, by producing striking morphological changes in the Koch bacillus, which, cloistered in a fat involucrum, seemed inviolable. The bacilli, developed in cultures mixed with a small concentration of isonicotinic acid hydrazide, look more transparent, are smaller, and are gathered in chains of underdeveloped elements or are discoid in shape; these changes have never before been observed in normal cultures. Bacilli fully developed put in contact with active doses of isonicotinic acid hydrazide also show changes and a tendency to form large conglutinates. It is interesting to note that cultures with a high inhibiting concentration of isonicotinic acid hydrazide left long enough show the development of precarious colonies. This experimental information has far-reaching practical consequences. We are firmly convinced that isonicotinic acid hydrazide attacks the bacilli and protects the host while it is being used, but that the protection is only temporary and ceases when the drug, at the end of the treatment, is completely eliminated through the kidneys in the form of nitrogen compounds. While the Koch bacillus is under attack of the drug, the host has better chances of building up its own defenses to carry on the struggle against the disease.

After a certain interval, not yet clinically or experimentally determined, the bacilli which have been attacked and have recuperated become resistant, or those which did not suffer the influence of the drug, because they were embedded in avascular fibrous or caseous lesions beyond the reach of the drug, may become aggressive again. An early observation of phthisiologists, particularly those in *Istituto Sanatoriale Principi di Piemonte*, in Naples, is that the isonicotinic acid hydrazide especially attacks the bacilli free in the secretions of lung cavities or ulcerated surfaces. It has a much reduced power against the bacilli which are well protected inside fibrous nodules or caseous foci. Resected specimens,

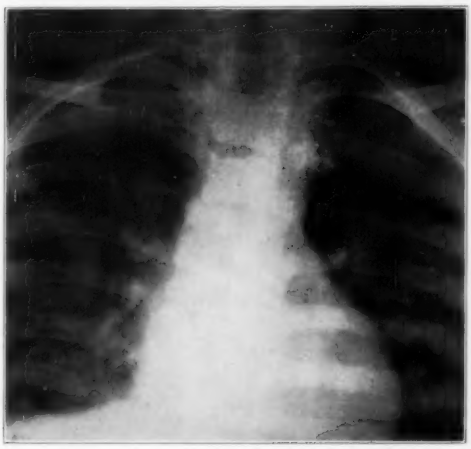

FIG. 18-A

FIG. 18-B

Figs. 18-A and 18-B: Primary complex of the upper left lobe of the lung. Botal lymph node has become calcified. The patient had extensive tuberculosis of the spine with total destruction of the lumbar vertebrae.

in patients with negative sputum and negative exudate, have been found extremely rich in virulent bacilli. The action of the isonicotinic acid hydrazide is especially directed against the evolving types of the disease and the products of disintegration of the tuberculous process, all of which swarm with live bacilli and are rich in toxic materials. These secretions, which are responsible for the toxic phenomena, are neutralized by the drug; this accounts for the sometimes dramatic effects in the general condition of the patient, in contrast with the insignificance of the local effects. Now that we know a great deal about the action of the drug on the active foci and on the bacilli, we wonder what the reactions of the organism are under this new treatment. In the first phase, the drug comes into

FIG. 19-A

FIG. 19-B

Extensive tuberculosis of the spine in a patient with normal lungs.

contact with the active lesions and provokes the dissolution of considerable numbers of bacilli, and liberates into the circulation specific antigens, which give rise to formation of antibodies. These acute changes, in the immunological phenomena, are accompanied by intense exudative perifocal reactions and increased sensitivity to the tuberculin test. It is of considerable significance that patients with long-standing lesions, given up as hopeless and already in the fourth stage of the disease in a state of anergy, may show acute specific allergic phenomena. These acute allergic transformations, responsible for strong focal hyperaemia, explain the usual observation of hemoptysis, when the treatment of lung tuberculosis with isonicotinic acid hydrazide is first started. The same principles apply, of course, to skeletal tuberculosis, but the observation of the different phenomena is much easier in the lungs because of the anatomy. Osteo-articular tuberculosis, even treated from the very beginning, contrary to the pulmonary disease, shows an almost

FIG. 20-A

Fig. 20-A: Tuberculous osteo-arthritis of the left hip. The sacro-iliac joint is intact.

Fig. 20-B: The patient was treated with streptomycin and para-aminosalicylic acid. The lesion of the hip became more extensive, but showed signs of limitation. The left sacro-iliac joint was involved.

FIG. 20-B

FIG. 20-C

FIG. 20-D

Fig. 20-C: An Albee-Brittain fusion considerably improved the hip. At this stage, treatment with isonicotinic acid hydrazide was begun.

Fig. 20-D: The sacro-iliac lesion became more extensive and decalcified.

FIG. 21-A

FIG. 21-B

Fig. 21-A: In a patient treated with isonicotinic acid hydrazide, there was a granular lesion on the bottom of the cotyloid cavity and a small erosive process at the upper rim.

Fig. 21-B: After treatment with isonicotinic acid hydrazide, there is intensive decalcification of the whole joint. Both lesions are definitely much worse.

	E	L	M	S	L/M
Case 1	0	20	4	-	5
	10	41	2	27/55	-
	H-20	24	2	38/62	12
	32	30	6	35/68	5
	8	72	2	20/48	36
Case 2	18	24	4	47/85	6
	4	28	2	70/92	14
	H-6	57	3	90/110	19
	8	32	4	94/105	8
	20	24	4	102/110	6
Case 3	8	32	6	25/32	5.3
	4	18	4	15/47	4.5
	H-8	22	4	15/38	5.5
	16	30	2	18/40	15
	4	18	4	15/47	4.5
Case4	6	21	5	55/82	4.2
	7	27	5	94/118	5.4
	6	38	4	112/120	9.5
	H-11	38	1	79/107	38
	5	36	12	-	3
Case 5	3	59	3	58/90	19.6
	4	36	4	39/58	9
	12	32	8	48/56	4
	H-4	42	4	35/54	13
	2	50	2	24/50	25

	E	L	M	S	L/M
Case 6	6	26	4	48/82	6.5
	12	30	8	34/63	3.8
	H-20	44	2	-	22
	4	17	3	24/53	5.6
	11	47	2	16/34	28.5
Case 7	2	22	4	-	5.5
	10	40	2	-	20
	6	36	12	-	3
	10	58	14	22/36	4.1
	H-8	42	2	23/35	21
Case 8	8	19	5	95/121	3.2
	0	14	2	133/133	7
	H-10	26	2	105/123	13
	4	42	3	50/88	14
	7	57	1	60/95	57
Case 9	9	28	3	32/56	9.3
	10	40	6	-	6.6
	0	12	8	22/45	1.5
	12	30	2	22/50	15
	H-17	40	1	23/40	40
Case 10	2	42	6	-	7
	1	45	5	23/70	9
	H-8	76	0	19/42	76
	7	50	4	28/57	12.5
	6	69	9	-	7.6

	E	L	M	S	L/M
Case 11	6	40	14	-	2.8
	10	24	2	-	12
	2	30	10	40/95	3
	H-11	36	0	32/55	36
	4	14	10	37/60	1.4
Case 12	6	24	4	10/38	6
	H-2	30	6	49/98	5
	31	40	2	-	20
	0	16	2	25/55	8
	12	38	2	64/93	19
Case 13	5	24	5	38/77	4.8
	3	12	3	46/75	4
	H-19	53	2	20/50	26.5
	6	34	2	18/23	17
	1	44	3	38/66	14.6
Case 14	3	27	4	-	6.7
	20	30	6	30/62	5
	H-0	54	0	-	54
	47	42	0	35/60	42
	15	47	1	28/60	47
Case 15	4	20	8	15/28	2.5
	2	32	8	8/23	4
	H-8	48	2	40/72	24
	8	30	2	8/23	15
	31	27	0	25/52	27

TABLE V

Typical hemograms in fifteen cases are shown. Counts were made before and after treatment with isonicotinic acid hydrazide. Note the extreme elevation of the lymphocyte-monocyte ratio. The sedimentation rate has not been influenced more than slightly. The beginning of treatment with isonicotinic acid hydrazide is marked *H*. (*E*, eosinophils; *L*, lymphocytes; *M*, monocytes; *S*, sedimentation rate; *L/M*, lymphocyte-monocyte ratio.)

uncontrollable tendency to evolve to the tertiary period. In preparation of this paper we examined the records of our first 100 patients treated with isonicotinic acid hydrazide, in some of whom previous treatment with streptomycin and para-aminosalicylic acid had failed. We studied the behavior of the bacillus in a closed joint with great curiosity, and made cultures and bacterioscopic and pathological examinations before and after operation, so as to make the necessary comparison of results. Of course such investigations are much more difficult in skeletal tuberculosis than in pulmonary tuberculosis and as yet we are not in a position to offer any definite conclusions. However, we have already observed some very interesting facts. Isonicotinic acid hydrazide shows quite rapidly a marked action on soft-tissue lesions, such as those in lymph nodes and in synovial membranes, but the drug has practically no action against lesions embedded within the thick walls of a destroyed capsule or the necrotic tissues of a secondary-tertiary joint lesion. It also seems that in the more serious and advanced lesions, resistant strains appear more rapidly. In roentgenograms of patients with osteo-articular tuberculosis, as it was to be expected, we did not observe the same rapid improvement of the evolving lesions as in the lungs, where we find them disappearing quite often without leaving any traces. The initial reactive phenomena of local hyperaemia with more intense decalcification than is usually observed seem very evident. This has a great practical significance because, due to the more intensive decalcification in the spine and in weight-bearing joints, the collapse of the articular surfaces is bound to appear at an early date and with more intensity. In

FIG. 22

Fig. 22: Typical fusiform abscess in the mid-thoracic spine. This quite often is complicated by paraplegia.

FIG. 23

FIG. 24

Figs. 23 and 24: Spines in two patients with extreme kyphosis. These patients suffered no paraplegia.

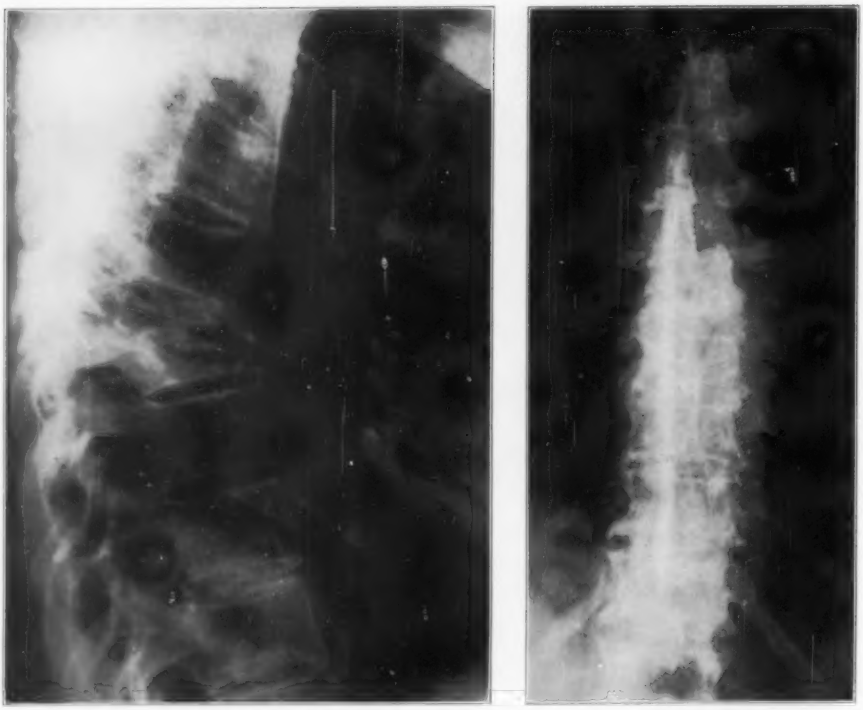

FIG. 25-A FIG. 25-B

Spinal tuberculosis of the granular exudative type in an adult patient with paraplegia. Cure of ten years' duration was obtained after an Albee fusion.

a large number of roentgenograms we have observed that the local lesion becomes worse at the beginning of the treatment. It develops in the same manner as if the bacillus were not affected by the action of the drug.

What we have observed is that the lesions show a tendency to heal much faster because they pass from the secondary to the tertiary stage much more rapidly. This is the striking phenomenon seen in the roentgenograms mentioned, and it is noticed quite often in less than six months to a year from the onset of the treatment. Again we can see that the evolution of a tuberculous lesion, with or without antibiotic or chemical treatment, is always directed by the biological phenomena of allergy. In Table V a selected series of hemograms of fifteen patients under treatment with isonicotinic acid hydrazide is given. The red blood count and hemoglobin changes are negligible, because they suffer only a temporary fall at the beginning of the treatment. Isonicotinic acid hydrazide produces striking changes, more important than those produced by streptomycin and para-aminosalicylic acid, in the relative count of eosinophils, lymphocytes, and monocytes. There is frequently an increase of the eosinophils, sometimes very marked, at the beginning of the treatment, but the count drops rapidly to normal.

However, more interesting changes are observed in the lymphocytes and monocytes. They always show an increase in the count of the lymphocytes, sometimes surprisingly high, and a drop in the monocyte count, elevating accordingly the lymphocyte-monocyte ratio, which often reaches the extremely high figure of *thirty-eight*, *forty-seven*, *fifty-seven*, or even *seventy-six*. The practical significance of the elevation of the lymphocyte-monocyte ratio has been discussed previously.

Isonicotinic acid hydrazide does not seem to have any significant influence on the sedimentation rate. In conclusion, we think that isonicotinic acid hydrazide, like streptomycin and para-aminosalicylic acid, is a great event in the fight against tuberculosis, and a tremendous adjunct to surgical treatment, which can now be done at an earlier date and with more safety than was ever possible before.

THE CARE OF THE PARAPLEGIC PATIENT

Of 550 patients with tuberculosis of the spine, forty-one (7.4 per cent.) had paraplegia of the lower limbs. One patient had quadriplegia caused by tuberculosis of the spinous process and posterior arch of the axis. Paraplegia, which we do not consider the dreaded complication others do, is more prone to occur in tuberculosis of the mid-portion of the thoracic spine, particularly in patients with early fusiform abscesses (Fig. 23). In paraplegic patients, we have never performed a laminectomy. We have never dared to use a lateral approach to the focus, unless the roentgenogram shows a large sequestrum inside the spinal canal, a possibility which we have never seen. The curettage of the whole focus, including small invisible granulating areas which are oftentimes situated far above or below the main focus, is beyond our comprehension. Paraplegia is caused by pressure on the cord by a tightly enclosed abscess or pressure by productive granulating tissue in the secondary period of the disease. The evolution of both Pott's abscess and granulating lesions is influenced by the general laws of tuberculosis and therefore is subject to spontaneous reabsorption. As such, paraplegic complications have a spontaneous tendency to regression. The crumbling of the spine in the serious progressive lesions leading to the third period, as a rule, happens slowly and the cord sustains only a gradual distention. We have seen many spines bent to an acute angle without any complications resulting. During the crumbling of the spine, sequestra are formed, which ordinarily are eliminated, anteriorly. The cord is extremely well protected by the posterior arch and the vertebral ligaments, which are structures seldom destroyed by tuberculosis.

All of our paraplegic patients have been cured under the routine treatment of general care, immobilization, and early fusion of the spine. Figures 25-A and 25-B show extremely severe spine tuberculosis with paraplegia which was permanently cured by spine fusion. We have never seen paraplegia develop in a patient after solid fusion of the spine. Permanently paraplegic patients, of whom we have had only a few, had chronic inflammation of the meninges which is not regressive, and cannot, of course, be removed by surgery. Any patient with spinal disease under treatment with isonicotinic acid hydrazide, which produces more rapid decalcification, is consequently in danger of more rapid collapse of the vertebral bodies and should be immobilized very carefully.

CONCLUSIONS

1. The evolution of tuberculosis is always directed by the general biological phenomenon of tuberculous allergy.

2. Streptomycin, para-aminosalicylic acid, and isonicotinic acid hydrazide have a definite influence on the evolution of the disease.

3. Sound arthrodesis still is indispensable to a complete cure in the majority of patients.

4. The pulmonary problem should be always carefully investigated in every case of skeletal tuberculosis.

5. Early arthrodesis is the best and the safest treatment for paraplegia.

6. Tuberculosis still is a social problem.

NOTE: In order to deal with skeletal tuberculosis properly, the orthopaedic surgeon must have the cooperation of a capable team. This team is composed of phthisiologists, bacteriologists, pathologists, laboratory technicians, and roentgenologists who are necessarily specialists in the field of tuberculosis.

We, in Jesus Hospital, have been very fortunate in having the valuable cooperation of Dr. João Fortes, Dr. Milton Bastos, Dr. Alcides Sa, Dr. Milton Fontes Magarão, Dr. Milton Costa, Dr. Ernani Torres, and Prof. Aluisio de Paula, and we are very grateful and are extremely indebted to all of them. I also wish to thank my friend and colleague Dr. Jorge Sardinha for his never-failing cooperation.

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ORTHOPAEDIC ASPECTS OF DIABETIC NEUROPATHY

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Diabetes is replacing syphilis as the great imitator since syphilis is now so easily treated. Because diabetic neuropathy is found in 5 per cent. of all diabetics, according to Rundles, these patients represent an important group presenting themselves for diagnosis.

It is now established that diabetic neuropathy is a specific neurological degeneration associated with the disordered metabolism of diabetics. Rundles considers that it is a reversible peripheral-nerve involvement with secondary degeneration of the spinal cord. Weight loss is frequently a precursor to neuropathy. The exact relationship of the weight loss, indicating fat catabolism and the metabolism of nerve tissue which depends primarily on carbohydrates, to the neuropathy is not clear. The important point is that the neuropathy is reversible if the diabetes can be well controlled. A patient in whom the diabetes has not been diagnosed previously, one who will not cooperate in the diabetic regimen, or a patient in whom the condition cannot be controlled by diet and insulin is very prone to have a neuropathy.

The classification of diabetic neuropathy is divided into three groups:

1. The hyperglycaemic type is characterized by tenderness along the nerve during the acute attack with rapid subsidence; therefore, it is not clinically important.

2. The circulatory type is characterized by peripheral paraesthesia, hyporeflexia, hyperaesthesia, and intermittent claudication with absent pulses. These are diagnosed easily and do not present problems from an orthopaedic standpoint.

3. The degenerative type is the condition that will be discussed here with its progressive signs and symptoms.

This study has been based on a series of twenty-seven cases of diabetic neuropathy which were severe enough to warrant the patients' being admitted to the Hospital for examination. Many more cases were not included in this study because of positive results in serological tests or because of other neurological lesions which would confuse the study for statistical purposes.

The ages of the patients varied from thirteen to sixty-nine, with an average age of forty-eight, which is lower than one might expect.

The severity of the diabetes did not seem to be an essential factor, since four patients had diabetes in a mild form which could be controlled by diet only. The fasting-blood-sugar values ranged from 73 to 600 milligrams per 100 cubic centimeters in this series. All except two of the patients had been admitted for investigation of symptoms related to the neuropathy, even though most of them were known to be diabetic. Five patients had lost considerable weight prior to admission.

Since the structure of the retina is closely related to the brain structure, diabetic retinopathy shows a close correlation with diabetic neuropathy. Seventeen of the patients (62 per cent.) had diabetic retinopathy or were blind as a result of cataracts. Rundles' series of patients with diabetic neuropathy showed that 34 per cent. had retinopathy, whereas 10 per cent. of his diabetics had retinopathy.

The positive symptoms are so variable that there are no characteristic symptoms, which accounts for the indefinite conception of the syndrome by most orthopaedic surgeons. Dull, burning, or shocklike pain occurs in the knees, ankles, hips, thighs, legs, shoulders, or wrists (the order indicates frequency of involvement). Characteristically, it is worse at night. Hyperaesthesia of the thighs or shoulders and numbness and tingling of

TABLE I

EXAMINATION OF REFLEXES IN TWENTY-SEVEN PATIENTS WITH DIABETIC NEUROPATHY

Reflexes	Reflexes Absent		Reflexes Diminished	Patients Showing No Changes in Reflexes	Patients Showing Some Changes in Reflexes (*Per cent.*)
	Bilaterally	Unilaterally			
Ankle	18	2	4	3	88.
Knee	8	4	7	8	70.
Biceps	4	1	7	15	44.
Triceps	5	1	7	14	48.
Abdominal	3	0	3	21	22.
Cremasteric	1	0	0	26	7.

the hands and feet are common. There may be hoarseness due to laryngeal paralysis. Changes in bladder or bowel habits may be complaints. It is easy to see why many of these patients come to the orthopaedic clinic at some stage in the disease.

The effects of diabetic neuropathy on the reflexes are of interest and indicate why the syndrome is called pseudotabes. Table I shows the results of examination of the reflexes in the twenty-seven patients. In all patients except one, any or all of the following reflexes were absent: the biceps, triceps, knee, and ankle jerks. One patient had a diminished ankle jerk when first seen; the second case report in this paper concerns this patient, who now has loss of ankle jerks and diminished knee jerks.

The sensory findings are variable. A characteristic finding is a zone of hyperaestnesia of no predictable dermatome distribution. Occasionally the hyperaesthesia surrounds a zone of hypo-aesthesia. Loss of the sensations of vibration, position, pain, temperature, and touch is sporadically noted to a greater or lesser degree, and such losses are strikingly unrelated to each other if found in one patient. This accounts for the development of diabetic arthropathy which is not being discussed in this presentation. This characteristic dissociation of the sensations produces the most confusion in assessing a case. One is struck by the variability of sensory findings from one examination to the next (obviously producing a strained intern-resident-staff relationship according to some of the charts reviewed).

The muscle power varies from normal to complete paralysis. One patient presented a paraplegia, but it was noticed that the wasting of the leg muscles was minimal in view of the great loss of function. The dorsiflexors of the ankle were involved in five patients, of whom one had complete foot-drop. It is interesting that two patients had hoarseness due to paralysis of vocal cords. Weakness of the muscles of the hands, arms, knees, and ankles was noted in this group in isolated instances.

The study of the cerebrospinal fluid is the most important laboratory aid in the diagnosis. Of the twenty patients whose cerebrospinal fluid was examined for proteins, only four had a protein content below 45 milligrams per 100 cubic centimeters. In most cases, it was between 65 and 100 milligrams per 100 cubic centimeters, with a high of 204 milligrams per 100 cubic centimeters. The tests of the cerebrospinal fluid with colloidal gold showed a low left curve of the order of 1122100000, if it was abnormal at all.

The prognosis is difficult to obtain from this series, since many patients had been sent in for diagnosis only, and no follow-up could be obtained. However, thirteen cases showed significant improvement after the diagnosis had been made and adequate insulin had been given.

Vitamins C, B_1, and B_{12} have all been popular at various periods and have been given without sufficiently accurate assessment to warrant comment. From the perusal of the

charts, there would seem to be no difference in the end results in the different eras, which confirms the conclusion of Joslin. Joslin ascribes the improvement following vitamin therapy to the deficiency of vitamins in the diabetic diets of the past. Accordingly, vitamin therapy occupies a large place in the therapeutic discussions without any justification. Control of the diet and insulin therapy, however, are followed by striking improvement in patients with recent symptoms and by the arrest of the disease, at least, in the long-standing cases.

ILLUSTRATIVE CASES

CASE 1. M. W., a woman, forty-two years old, was admitted to the Medical Service in July 1952, from the Diabetic Clinic because of back pain and a recent thirty-pound weight loss. The fasting-blood-sugar values ranged from 156 to 268 milligrams per 100 cubic centimeters.

For two months she had had intermittent aching in the lumbar region with radiation of the pain from the right lumbar region down the right thigh and leg and around the right pelvic area. It was not made worse by coughing and sneezing; but it was much worse at night.

A healed and symptomless tuberculous lesion was noted at the third and fourth thoracic vertebrae, which had been treated at the age of fourteen; the most recent flare-up had occurred nine years before admission.

Diabetes had been diagnosed nine years previously but had been treated by diet only with no further check-up. At the onset of the present symptoms, the patient's local doctor had started her on ten units of insulin a day. She continued to lose weight and had lost thirteen pounds between the time she was examined by her local doctor and her admission to the Hospital two months later.

The medical opinion was that she had a thyrotoxicosis, although this could not be proved in spite of very extensive tests. The orthopaedic opinion was that she had a chronic low-back strain. The neurologist felt that a cord tumor should be ruled out. The diabetes was stabilized on the Diabetic Service, and the patient was discharged with a back brace, somewhat improved.

She was admitted to the Orthopaedic Service three months later, since the pain was sufficiently severe to keep her from working. The back brace had not helped.

The examination revealed a full range of movement in the back and hips. The pain was localized to an area of hyperaesthesia in the lower part of the back and down the anterior aspect of the thigh. The biceps and triceps reflexes were diminished and knee and ankle jerks were absent. The cerebrospinal fluid showed a protein level of 91 milligrams per 100 cubic centimeters and normal pressure. The caloric intake was increased, and the insulin was increased to twenty units a day.

When the diabetes had been brought under control, the symptoms dramatically improved. Sensation returned to normal. However, four months after treatment, when the patient had returned to work, no improvement in the reflexes was noted.

The elevated cerebrospinal-fluid protein, the hyperaesthesia, and the loss of reflexes had suggested the diagnosis.

CASE 2. T. L., a woman, fifty-eight years old, was admitted to the Department of Neurosurgery in January 1953, after having been followed in the Diabetic Clinic since 1939, when treatment with eighty units of insulin a day had been prescribed. The fasting-blood-sugar values ranged up to 312 milligrams per 100 cubic centimeters. Usually the diabetes was under poor control, resulting in fluctuations of weight and urinary sugar, in spite of firm instructions to the patient. A recent weight loss was recorded. The past history was significant in that she had had a chordotomy for intractable pain of unknown etiology in the left hip in 1947, with improvement.

The patient's complaints on admission were of a sharp, knifelike, constant pain of three and one-half weeks' duration in the left supraclavicular and scapular areas, which radiated down to the left hand. It was made worse by movement of the left shoulder and elbow, and she was unable to lie on her back or left side. Her voice had been hoarse for two weeks. She was referred to the Orthopaedic Clinic for treatment of a frozen shoulder on the basis of some minimal stable calcification seen in the roentgenograms.

Examination revealed a moderate degree of retinopathy. There was hyperaesthesia of the entire left shoulder area extending down to the elbow. When the patient was seen first, she was reluctant to move the shoulder, but the extremity could be passively abducted well above a right angle, if it were done carefully and gently. Palpation revealed no tenderness over any anatomical structure. The arm had to be held firmly to avoid stimulation of the skin; gentle stroking of the skin was much more painful than deep pressure. She was concerned about the pain in the region of the chordotomy scar, but examination confirmed that this was also due to hyperaesthesia, which prevented her from sleeping on it.

Paralysis of one vocal cord was noted, accounting for the hoarseness. She is one of the four patients in whom the cerebrospinal-fluid protein content was normal, although it had been 53 milligrams per 100 cubic centimeters five years before. Her ankle reflexes were absent, and knee jerks and left biceps reflexes

were diminished. The patient had a complete examination, including a myelogram and consultations with twelve departments. However, no other lesion was found to account for the clinical picture. She has improved slightly.

Although the pain and hypersensitivity improved with more rigorous treatment of the diabetes, the objective examination showed no improvement. The diabetes was of such severity that the blood-sugar level could not be stabilized. Since no further lesions had developed in her back or hip, the intractable pain for which the chordotomy had been performed three years before was probably due to diabetic neuropathy.

Case 3. T. C., a man, sixty-nine years old, was admitted to the Hospital for leg pain of two months' duration. He had first noticed the pain in the left ankle after walking and described it as a constant deep ache ("felt as if in the bone"). It gradually extended to involve the whole left lower extremity and the hip region. The pain was worse after he had been moving about, but it was not influenced by coughing or straining. Slight weakness of the extremity was noted.

Physical examination showed slight atrophy of the left thigh and calf (1.25 centimeters). There was marked diminution of power in the quadriceps and the dorsiflexors. The sensory examination revealed the absence of vibration sense below each knee, the absence of deep pain and tendon pain in the left leg, and the absence of pain and temperature sensation over the medial aspect of the left calf. The examination for reflexes was interesting in that the knee and ankle reflexes were absent on the left side only.

This patient had been treated for diabetes for five years by diet only until just before he was admitted. His fasting-blood-sugar values ranged between 98 and 270 milligrams per 100 cubic centimeters while he was in the Hospital. It was difficult to control the diabetes. Extensive laboratory tests were done with the following significant findings. The cerebrospinal fluid showed no cells, and the Kolmer test was negative, but there was a protein content of 95 milligrams per 100 cubic centimeters. Lumbar and cisternal myelograms were normal.

The patient's pain decreased as the diabetes was controlled over a period of three weeks. This patient has been followed for three years, during which time there have been continued improvement in muscle power and diminution of pain. The tests for sensation and reflexes demonstrate no improvement. However, control of the diabetes frequently was not maintained. No other neurological signs have developed.

Case 4. M. H., a woman, sixty-four years old, was admitted in December 1946 to the Hospital with an eight-months' history of progressive paraplegia which had started with pain in the left knee and weakness of the left lower extremity. In May 1946, weakness of the right lower extremity had begun which had progressed so that in July 1946 she had been unable to get out of bed without aid. In September, burning pain and numbness developed in the left hand and fingers, associated with weakness of the grip. On admission, it was found that similar symptoms were developing in the right hand. For one month before admission, she had had some incontinence associated with polydipsia and polyuria.

Physical examination revealed an obese individual who was unable to walk. The weakness of the grasp of the hands was confirmed, and there was a generalized weakness of all the muscles of the upper extremity which was more marked in the extensors. Reflexes were symmetrical. A Babinski reflex and ankle clonus were noted. There was decreased appreciation of sensations of heat and cold and of pin-prick and light touch below the umbilicus on the right.

The fasting blood sugar was 250 milligrams per 100 cubic centimeters and urinalysis showed a sugar content of + + + + but no ketones. The spinal fluid showed pressure of 140 millimeters of water, no white blood cells, protein content of 72 milligrams per 100 cubic centimeters, a negative Kolmer test, and a normal colloidal-gold curve.

The patient was treated for three weeks by the Medical Department, as the diabetes had never been previously suspected. During this time, the pain in her hands disappeared and the muscle strength improved. There was definite subsidence of the sensory disturbance on the right side.

This patient presented a striking picture of rapid improvement in her symptoms when the diabetes was controlled. Long-term follow-up to determine if the reflexes have recovered has not been possible.

In summary, diabetic neuropathy is a condition of degeneration of the nervous system. Sensory-tract lesions are manifested, such as hyperaesthesia, paraesthesia, hypoaesthesia, loss of sensations of position, sense, pain, and temperature to varying degrees. Motor-tract lesions are manifested by weakness, particularly of the hands, the quadriceps, and the dorsiflexors of the ankle. Sympathetic and parasympathetic nerve involvement is less common. Diabetic retinopathy is a common complication. The cerebrospinal-fluid examination, although not pathognomonic, is characterized by moderate elevation of the protein content with a normal cell count and pressure. The recent changes are reversible if the diabetes can be controlled.

In conclusion, diabetic neuropathy must be considered when a diabetic patient (or a patient with polyuria and polydipsia) complains of symptoms that are not absolutely typical of an orthopaedic syndrome.

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NEUROGENIC ARTHROPATHY ASSOCIATED WITH DIABETES MELLITUS

Review of the Literature and Report of One Case in a Juvenile Diabetic

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Neurogenic arthropathy (Charcot joint) associated with diabetes mellitus has rarely been reported in the English literature [7,10,18]. Charcot joint in juvenile diabetes mellitus has been reported on only one occasion with a presentation of two cases[7]. In the existing reports on necrosis of bone and joints in diabetes mellitus, all patients, with one exception, have been in older age groups, averaging fifty-six years of age at the time of appearance of Charcot lesions. Bailey and Root found seventeen cases of neuropathic foot lesions in 20,000 consecutive cases of diabetes mellitus reviewed. Diabetes mellitus in this group had been present for an average of eleven and one-half years. Jordan, in 1943, reported three patients with Charcot joints who were diabetics; they were aged sixty-eight, forty-seven, and fifty-two years, and the duration of the diabetes in these cases was fifteen, twenty-two, and seven years, respectively. Jordan noted involvement in the small joints of the toes, tarsal bones, and lumbar vertebrae. Shore, in 1947, treated one diabetic patient who had destruction in the left knee joint. This patient had diabetes of long duration associated with peripheral-nerve changes manifested by loss of reflexes, loss of vibratory sense, and night pain. He was unsuccessful in preventing further destruction of bones and joints, after regulation of the diabetes and vitamin B_1 therapy. His impression was that Charcot joints were rare in association with diabetes mellitus. Muri reported a Charcot joint of the ankle developing in a male diabetic forty-three years old after an eighteen-year history of diabetes mellitus. Postmortem examination showed moderate neuritic changes of the posterior tibial nerve, slight retrograde changes of motor neurons of the spinal cord, and intercapillary glomerulosclerosis. Wilson, McIntyre, and Albertson reported a patient with tarsal and phalangeal involvement, without peripheral-nerve manifestations but with a high spinal-fluid protein and a low cell count. They concluded that the type of reaction seen in this patient and in others may point to a radiculoneuritis as the etiological factor.

Pain and paraesthesia in the lower extremities concomitant with diabetes mellitus have been described for over fifty years. Jordan stated, "it is a frequent symptom and not infrequently is the presenting complaint". The percentage of diabetics in this series who

had associated peripheral-nerve involvement was as high as 45 per cent. The complaints were night pain, paraesthesia, and tingling.

Of 110 diabetics hospitalized at the United States Public Health Service Hospital, Baltimore, Maryland, between July 1, 1953, and June 30, 1954, twenty-eight patients complained of thigh, calf, or foot pain and of paraesthesia. Eight of this group complained of neuritic pains involving upper extremities and shoulder regions. Two patients exhibited bone changes in the nature of Charcot joint lesions. The patient with the most advanced bone and joint changes will be reported in this paper. Our second patient was a female, now aged thirty-one, who has been a diabetic since age seventeen. At the present time involvement is limited to the interphalangeal joints of her left foot. It is worthy of note that it is in this extremity that her pain is more intense and of longer duration than in her other extremity.

The incidence of neurological symptoms in diabetes mellitus varies according to various series from less than 1 per cent. to more than 50 per cent. These statistics may be open to much question, since they are from chart reviews of the patient's history.

According to Bailey and Root, the earliest detectable sign or finding is unilateral or bilateral thickening in the tarsal region. The swelling is painless and without redness or heat. Roentgenograms show destruction of bone with fragmentation and no clean-cut fracture lines. A history of traumatic injury may be given. Apparently the danger of trauma from walking on an insensitive foot is always present. A pathological fracture may be seen on roentgenograms. The patient may continue to walk and to use his extremity, because the bone destruction does not increase the pain of the pre-existing neuropathy. The knee and ankle reflexes are diminished. Additional trophic changes, such as ulcers on weight-bearing portions of the foot, may be found. The nails may or may not be brittle. The skin temperature may be only slightly decreased.

Concerning the etiology of Charcot joints in diabetes, opinions vary as to this still unexplained phenomenon. Ischaemic changes due to arteriosclerosis have been considered but certainly have not been borne out by experience, either in the patients reviewed or in the younger patients with good arterial pulsations. Syphilis has been ruled out by the absence of historical, clinical, or serological evidence. Syringomyelia in any form has been ruled out. According to Foster and Bassett, the lesions "appear to be predominantly extramedullary, with the major involvement in the posterior roots, the posterior root ganglia, and the sensory components of the peripheral nerves with relative sparing of the ventral roots and motor fibers of the peripheral nerves. A high concentration of protein in the spinal fluid is characteristic of the Guillain-Barré type of radiculoneuritis, in which there are anatomic changes in the posterior roots and posterior root ganglia"[12]. The work of Eloesser showed that any joint deprived of sensation requires, in addition, trauma to produce a typical Charcot joint.

The pathological examination of bone reveals complete loss of structure, with numerous spicules of bone, scattered throughout the area of involvement, undergoing various stages of absorption with minimal attempts at regeneration. There is some attempt on the part of the periosteum to form new bone. This lesion in bone is identical to that seen in neuropathic arthropathy of syphilis and syringomyelia.

CASE REPORT

L. S. (145399), a white male seaman, twenty-eight years old, was admitted to the orthopaedic service of the United States Public Health Service Hospital, Baltimore, Maryland, by transfer from the United States Public Health Service Hospital, Detroit, Michigan, on July 29, 1954. The chief complaint was ulceration on the plantar surface of the right foot, under the second metatarsal head, of three months' duration, and a deformed left foot due to old fracture of one year's duration.

The patient was a juvenile diabetic with a difficult regulation problem since the age of twelve. At admission the patient was taking forty units of regular insulin and twenty units of protamine zinc insulin daily, and had last been on a 2800-calorie diabetic diet. He had had insulin shock many times and had had two

FIG. 1

FIG. 2

Fig. 1: The roentgenogram made in May 1953 showed a pathological fracture of the tarsal navicular.

Fig. 2: The roentgenogram made in May 1954 showed a pathological fracture of the body of the left calcaneus and avulsion of the insertion of the tendo achillis. There was healing of the sustentaculum tali, but dissolution of the talar, navicular, and cuneiform joints was noted.

episodes of acidosis, the last time in 1952. The deformed left foot was relatively asymptomatic. He had been taking one-half grain codeine regularly for pain in the right foot. The patient also stated that he had had bilateral leg pain, particularly at night, for many years.

Past History

The patient had had six admissions to the Detroit Public Health Service Hospital for diabetes mellitus and its complications.

First admission, November 12 to December 3, 1951: The patient was treated for regulation of his diabetes.

Second admission, April 1 to May 22, 1952: The patient was again admitted for regulation of his diabetes. At this time it was first noted that he had bilateral ankle swelling, hypo-algesia of the fourth and fifth lumbar and the first sacral dermatomes bilaterally, and absence of knee and ankle jerks.

Third admission, November 8 to December 8, 1952: The patient was again admitted for regulation of his diabetes, complicated by an upper respiratory infection which was treated with penicillin.

Fourth admission, May 11 to August 20, 1953: The patient was admitted for painful swelling of the left foot of five days' duration after the foot had been stepped on by a shipmate. Roentgenograms revealed a comminuted, impacted fracture of the tarsal cuboid and navicular for which the patient was immobilized in a plaster cast for six weeks and thereafter treated with elastic bandages, physiotherapy, and Berger's exercises. He was discharged with a molded leather arch support for the left foot.

Fifth admission, November 13, 1953, to April 26, 1954: The patient was admitted with pain and deformity in the left foot; the pain was worse at night. Anaesthesia over the dorsum of the left foot was noted, as well as increased cerebrospinal-fluid protein. Roentgenograms at this time revealed disorganization of the joint surfaces of the calcaneus, talus, navicular, and adjacent bones. Left lumbar sympathectomy was performed on November 30, 1953, and biopsy of the talus was done on January 6, 1954. The left leg was again placed in a cast on April 9, 1954, and a walking iron was added on April 26, 1954.

Sixth admission, May 24 to July 29, 1954: The patient was readmitted for a perforating ulcer on the plantar surface of the right foot over the distal end of the second metatarsal. Swelling and deformity were present in the left foot, and both ankle jerks and the left knee jerk were absent. Hypo-algesia on the plantar surfaces of both feet was noted. Roentgenograms revealed, in addition to the previous bone destruction of the left foot, fragmentation in the left calcaneus. The left leg was again placed in a cast, and the ulcer on the right foot was treated conservatively with local applications and dressings.

Physical Examination

The patient was an asthenic, pale, young white male with normal vital signs, whose chief physical abnormalities were confined to the lower extremities. There were numerous, deeply pigmented scars over both legs, with increased warmth and rubor of the left lower extremity. There was a deformity of the left tarsal region. Dorsalis pedis and tibialis posterior pulses were palpable in both lower extremities but were slightly diminished on the left side. Knee and ankle jerks were absent bilaterally. The Romberg test was negative. Pinching of the heel cord was painful. Proprioceptive and vibratory senses were intact. There was

generalized, diffuse, diminished sensation to pinprick over both lower extremities, from the knee joint to the toes. There was loss of sensation to touch of a tuft of cotton in both lower extremities distal to a point halfway below the knee. Loss of temperature sensation (hot and cold) was present in both legs. Skin-resistance studies with the Richter electrodermometer revealed complete sympathetic denervation in a symmetrical pattern below the knees.

Laboratory Findings at Admission

Urine:

Albumin	110 milligrams per 100 milliliters
Sugar	None
Reaction	Acid
Specific gravity	1.014

Microscopic study revealed many white blood cells per high-power field.

Blood:

Hemoglobin	11.5 grams per 100 cubic centimeters
White blood cells	7,200 per cubic millimeter
Neutrophils	56 per cent.
Lymphocytes	38 per cent.
Monocytes	6 per cent.
Hematocrit	38 per cent.
Blood chemistry	
Urea nitrogen	21 milligrams per 100 cubic centimeters of blood
Fasting glucose	135 milligrams per 100 cubic centimeters of blood
Carbon dioxide	27.5 milli-equivalents per liter of blood
Serum chlorides	105 milli-equivalents per liter of blood

The serological tests for syphilis were negative.

Spinal fluid:

Red blood cells	1 per high-power field
Sugar	380 milligrams per 100 cubic centimeters
Chlorides	740 milligrams per 100 cubic centimeters
Colloidal gold	0000000000
Globulin	Positive
Total protein	144 milligrams per 100 cubic centimeters

Microscopic examination of the biopsy specimen disclosed a loss of general structure, with many spicules of bone appearing in a fibrous matrix. The latter contained scattered focal and diffuse infiltration of plasma cells, lymphocytes, and histiocytes. A few long spicules, most often adjacent to the periosteum, are "marginated" by osteoblasts, but more often osteoclastic activity is seen. These cells occupy lacunae in the ragged margins of the bony spicules. Diffuse fibroblastic proliferation is evident, and occasional arterioles show subintimal thickening.

Hospital Course

The patient's diabetes was controlled with regular insulin, forty units, and protamine zinc insulin, twenty units, daily, and a 1,800-calorie diabetic diet. The patient received vitamin B_{12}, forty-five milligrams daily. The ulcer on the right foot was treated with conservative measures consisting of bed rest, whirlpool baths, paring of callosities, débridement, and oral doses of penicillin. This proved to be effective in causing the ulcer to heal completely in two months. The patient was fitted with fleece-lined shoes and with a weight-bearing brace extending to the tibial condyle on the left leg. Since he continued to have severe rest pain in his legs and demanded narcotics, he was started on intramuscular doses of ACTH, forty-five milligrams daily, for ten days. His disposition improved. When questioned he stated that his pain had lessened since he had been receiving ACTH medication. It was then continued for an additional ten days. Recheck roentgenograms were made, and early healing of the pathological fractures was noted.

DISCUSSION

It is now generally recognized that the neurotrophic joint of Charcot may occur in diabetes as well as in syphilis and syringomyelia. Seventeen cases of diabetic arthropathy were reported by Bailey and Root, and five others were found in the literature in 1951[16]. The remainder are mostly isolated case reports with discussion of the syndrome [2,14,15,19,22]. Inadequate sensation, motor instability, laxity of tendon and ligaments, and hyperaemia

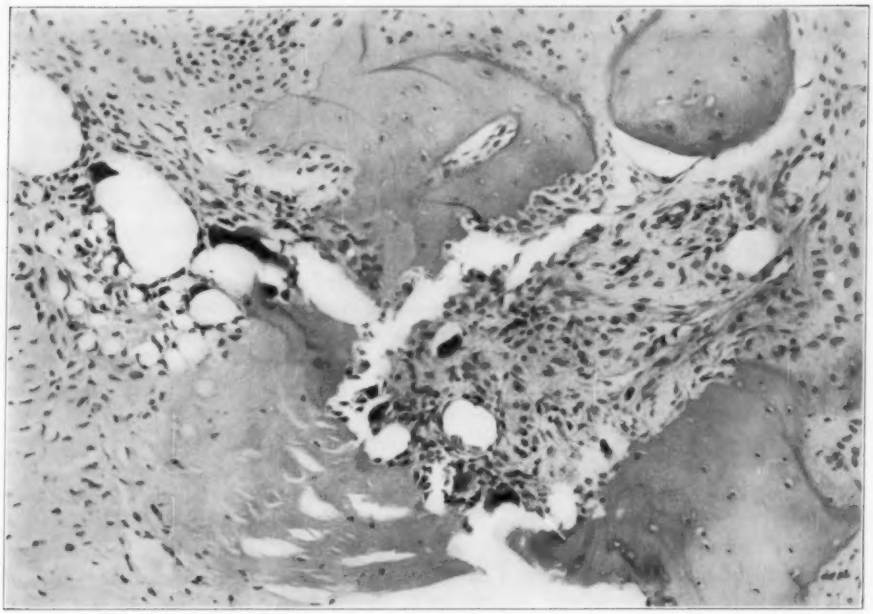

FIG. 3

Photomicrograph (× 100) showing a section from a biopsy specimen obtained from the left talus in November 1953. There was loss of general structure, with many spicules of bone appearing in a fibrous matrix. The latter contained scattered focal and diffuse infiltration of plasma cells, lymphocytes and histiocytes. A few long spicules, most often adjacent to the periosteum, were "marginated" by osteoblasts, but more often osteoclastic activity was seen. The osteoblasts occupied lacunae in the ragged margins of the bony spicules. Diffuse fibroblastic proliferation was evident and occasional arterioles showed subintimal thickening.

of the synovial membrane [3], as well as repeated small traumata [5], contribute to the subluxations and fractures around the joint. The term "trophic," originally applied to the joint by Charcot, still applies and includes (1) repeated trauma, (2) intact motor power, (3) an anaesthetic joint, (4) loss of proprioceptive impulses from the joint, (5) chronic neurological disease, and (6) metabolic disease [7]. Delay of pain conduction, anywhere from twenty to eighty-five seconds, at a histamine wheal is found, while the normal reaction is instantaneous. Slow-conducting pain fibers (non-myelinated C fibers), operating at one to two meters per second, remain intact, while rapidly-conducting myelinated fibers of thirty to eighty meters per second are affected [3]. Clinically, the arthropathy is found to occur in patients with poorly regulated diabetes of long standing. There is change of sensation, areflexia, and no palpable tenderness over the involved muscles and nerve trunks. History and clinical evidence of syphilis and syringomyelia are absent. The neuropathy involves extramedullary posterior root ganglia and is associated with high cerebrospinal-fluid protein without increase in cells (typical of Guillain-Barré radiculoneuritis). The disturbance of the peripheral nervous system associated with the neuropathic joints has been discussed by various authors [4,9,20], while others have described medullary changes typical of diabetes with sclerosis of the posterior columns [17,21]. A typical joint lesion is found in the presence of metabolic disorder (diabetes mellitus), peripheral vascular disease, sepsis, and diabetic neuropathy [14]. The neurological disturbances, rather than vascular ischaemia, are now considered to account for the presence of foot lesions in diabetes, particularly in older patients in whom advanced neuropathic changes occur. The joints usually involved in the lower extremity are the interphalangeal,

metatarsophalangeal, and tarsal joints. There is disorganization of the joint structure and deformity of the bones. There is no evidence of infection [16]. The slow progression results in a deformed foot, but arthropathy may develop rapidly, with sudden swelling as in the original description of Charcot. The prognosis for these extremities is poor. Some neuropathic arthropathies tend to become arrested and, apart from the deformity, cause little trouble. In others amputation is necessary [7]. The treatment is palliative and consists in orthopaedic appliances which prevent weight-bearing and further deformity of the foot, such as arch pads, tibial weight-bearing braces, and high, fleece-lined shoes. For the underlying diabetic neuropathy, treatment with brewer's yeast, high dosages of vitamin B_{12}, and ACTH has been suggested.

Martin [13], in a diligent search for neuropathic lesions in a series of 150 diabetics, found an incidence of 6 per cent. He found a 1.22 per cent. incidence of bone and joint lesions in his series and noted that only thirty-seven cases of the latter had been reported in the world literature by 1953. Reviewing his nine patients with arthropathy, he felt that perforating ulcers and neuropathic joints occurring together are independent of each other and are both due to peripheral-nerve disorder.

SUMMARY

In the cases reported the only constant finding has been that diabetes mellitus has been present for a long period of time. Nerve damage, with involvement of the peripheral nerves, of the nerve roots, or of the posterior columns, has been the most consistent pathological finding. It is manifested by sensory, vibratory, and reflex changes. Benefit from the use of ACTH seems to be present. It has probably resulted in lessening of the leg pain and healing of pathological fractures.

NOTE: We wish to express our appreciation to Dr. Thomas L. Shinnick, United States Public Health Service Hospital, Detroit, Michigan, for sending us this patient.

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CONGENITAL FLEXION-ADDUCTION DEFORMITY OF THE THUMB (CONGENITAL "CLASPED THUMB") *

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Five patients with congenital flexion-adduction deformity of the thumb have been seen during the past five years. Three of these patients, seen shortly after birth, responded well to plaster immobilization; the fourth patient, seen at age two, responded fairly well; the fifth patient, seen at age nine, required surgery.

Congenital absence of the extensor pollicis longus tendon was reported by Zadek in a child two and one-half years of age. This child was successfully treated by tendon transfer. Pollex varus was reported by Miller in two patients. One of the patients, eight weeks of age, was treated by casts and manipulation. More recently White and Jensen reported eight cases of this deformity, which they called "the infant's persistent thumb-clutched hand." Three of these patients were treated by tendon transfer. It is our opinion that the condition described by these authors is of the same nature as that seen in the five patients in our Clinic.

DIAGNOSIS

Congenital flexion-adduction deformity of the thumb is characterized by extreme flexion of the digit at the metacarpophalangeal joint and by adduction into the palm

* Read at the Annual Meeting of the American Society for Surgery of the Hand. Los Angeles, California, January 28, 1955.

(Fig. 1-A). The digit is held in the palm by the grasp of the overlying fingers. Hypermobility exists at the metacarpophalangeal joint. In the infant, when the grasp of the overlying fingers has been released, passive extension is carried out with ease. Active extension, however, is not manifest (assuming extensor tendons are present) until the thumb has been held out of the palm by the splint for several months (Cases 1, 2, 4, and 5). The condition should be differentiated from others which are similar.

Chronic stenosing tendovaginitis (trigger thumb): Passive extension of the distal joint is limited or associated with snapping. Treatment is tendovaginotomy.

The thumb in spastic paralysis: Here the thumb is caught beneath the tightly flexed

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1, one month old. Thumbs severely adducted into palms. No active extension.

Fig. 1-B: Two and one-half years after correction.

fingers. Flexion at the proximal thumb joint is usually not so marked as it is in flexion-adduction deformity. When the tightly flexed fingers have been opened, the thumb exhibits active extension.

The thumb in arthrogryposis: This condition is manifested by limitation of active and passive joint motion. Usually there is resistance to passive extension of the thumb rather than hypermobility of the metacarpophalangeal joint, as seen in cases of flexion-adduction deformity.

CASE REPORTS

CASE 1. C. M., one month old, was born with deformities of both hands and feet and with mild flexion contracture of both knee joints. There was no known familial history of congenital deformities.

The thumbs were severely flexed and adducted into the palms (Fig. 1-A), where they were held tightly clasped by the fingers. There were flexion contractures of the fingers; all the digits were long. The cleft between the thumb and index finger was tight bilaterally when the thumbs were passively extended. There was abnormal mobility at the metacarpophalangeal joint of each thumb. There was no observable active extension of the thumbs, although passively they could be brought into normal functional alignment with ease.

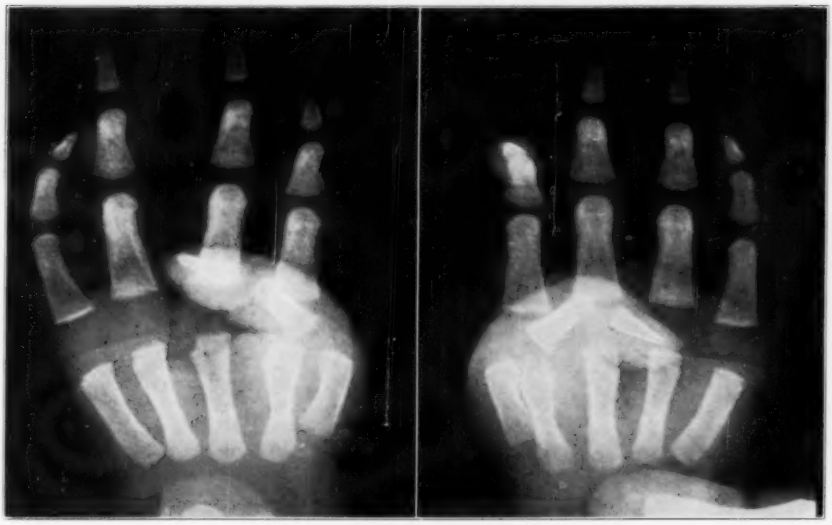

FIG. 2-A

Case 2. X-rays of hands when patient was six weeks of age. Thumbs held constantly in this position with fingers clasped over them. No active extension of thumbs.

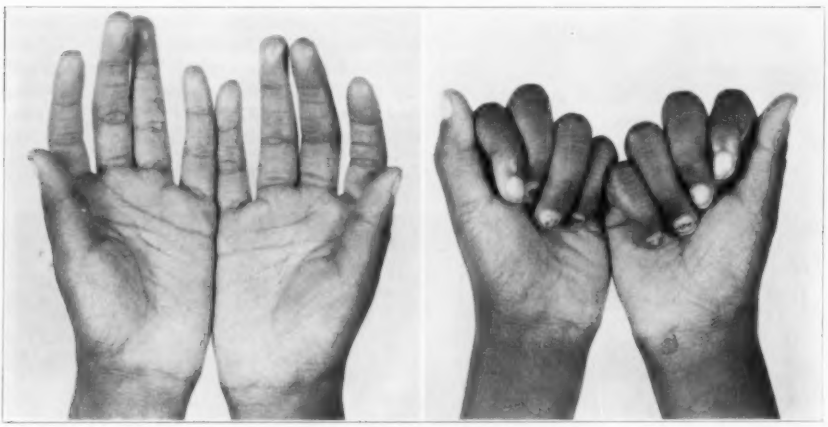

FIG. 2-B

Five years after correction. Active extension excellent.

Plaster casts were applied, holding the thumbs in functional alignment and the fingers in extension. To allow for growth, the casts were changed at intervals of six to eight weeks. The right thumb was immobilized for five and one-half months and the left, for seven and one-half months. When the casts had been removed, the patient spontaneously held his thumbs in good alignment, and at once it was apparent that there was active extension.

Figure 1-B shows the results at follow-up examination two and one-half years later. Subsequently, plastic procedures of the Z type were carried out on the tight band between the thumbs and index fingers. At present, the child is five years old and uses his thumbs and fingers quite normally.

CASE 2. C. F., six weeks of age, was unable at birth to extend the thumbs. No other abnormality was noted. The mother exhibited abnormal mobility of her proximal thumb joints but had no other abnormalities. One sibling was subsequently born with a club foot.

Examination showed both thumbs flexed and adducted into the palm (Fig. 2-A), where they were held in this hyperflexed position by the overlying fingers. There were no associated flexion contractures of the

fingers. No active extension was observed in the thumbs, but passively they could be readily extended. Active flexion was present but did not seem to be excessively strong. When the thumb had been brought into extension, a band of soft tissue was found between the base of the thumb and the base of the index finger, bilaterally.

FIG. 3-A

Case 3, age fifteen months (from old hospital record).

Bilateral plaster casts, changed at intervals of six to eight weeks, held the thumbs in functional alignment for seven and one-half months. The child then extended her thumbs actively and normally. Figure 2-B shows normal alignment of thumbs at age five.

CASE 3. W. M., nine years of age, had been born with congenital deformities of both hands and torticollis and later developed severe scoliosis. The left upper extremity showed absence of the thumb and flexion contractures of the fingers and elbow. The right upper extremity showed flexion-adduction deformity of the thumb and flexion contractures of the fingers, which were held tightly flexed over the adducted thumb. Figure 3-A (obtained from an old hospital record) shows the child at fifteen months.

Figure 3-B shows the condition of the hands when the patient was first seen at nine years of age. The flexion contractures of the fingers and the flexion-adduction deformity of the right thumb remains. There were tight soft-tissue bands on the volar surfaces of the fingers and between the base of the thumb and the index finger on the right hand.

The proximal thumb joint was fused surgically to hold the thumb in functional alignment, and free full-thickness skin grafts were applied to the volar surface of the thumb and fingers to overcome the soft-tissue contractures. Figure 3-C shows the result. The thumb was made functional, although active extension remained

FIG. 3-B

Hands when first seen, the patient then being nine years of age.

poor. The flexion contractures of the fingers were improved but not completely overcome.

Partial failure in this instance is attributed to the late stage at which correction was carried out. Permanent joint changes had already occurred in the fingers, and it is felt that the overstretched extensor tendons of the thumb had been permanently damaged.

CASE 4. W. M., two years of age, had been born with congenital deformities of both hands, club feet, large inguinal herniae, and pyloric stenosis. Family history was negative for previous congenital anomalies.

Examination showed flexion-adduction deformity of the thumb, bilaterally, associated with flexion contractures of the fingers. The position of the left thumb was more extreme than that of the right.

Casts were worn for three months. The right thumb shows good correction, but the left is still rather unstable.

CASE 5. M. W., eleven weeks of age, was born with the thumbs clasped in the palms. The only associated abnormality was a slight limitation of extension of the left elbow. There was no known familial history of congenital anomalies.

FIG. 3-C

After fusion of proximal thumb joint. Active extension poor due to late treatment.

The thumbs were adducted into the palms and held there by the flexed fingers. No active extension of the thumbs was observed. Passively, the thumbs could be extended normally. No contractures of the fingers and no particular tightness between the thumb and the index finger existed.

Plaster casts were worn for one month on the right hand and three months on the left (Fig. 4-A). The result, six months later, is shown in Figure 4-B.

DISCUSSION

Normal newborn infants hold their hands closed much of the time. They also clasp their thumbs. Among thirty-six newborn infants observed in the nursery at University Hospitals, fifteen (42 per cent.) held their fingers clasped over the thumbs part of the time. It was also noted, however, that the grasp of the fingers was released periodically and that the thumb then moved freely out of the palm.

Bieber states that the thumb in the newborn infant plays no role in grasp and that it usually lies dormant in the palm surrounded by the other digits. The studies of Gesell indicate that the infant begins to use its thumb in grasp at about three to four months of age.

In the five cases presented here, it appears that either the reflex clasp of the fingers upon the thumb was greater than normal or that weakness of the extensor tendons of the thumb allowed it to remain beneath the clasp of the fingers. Duchenne has shown that the proximal phalanx of the thumb becomes more flexed when the short extensor loses its action. White and Jensen ascribe the deformity in their cases to absence of the extensor pollicis brevis tendon. In our cases, with the possible exception of Case 3, the deformity was caused by weakness rather than by absence of the thumb extensor. Weakness of the extensors is undoubtedly accentuated by the over-pull of the flexors and the clasp of the fingers.

Associated flexion contractures of the fingers might have been an additional factor in three of our cases; in the other two they were not present. Some tightness in the web space between the thumb and the index finger, which was present in three of the cases, may also have been a factor. All the patients exhibited abnormal mobility of the metacarpophalangeal joints. The possible role of the grasping reflex when the thumb is in the

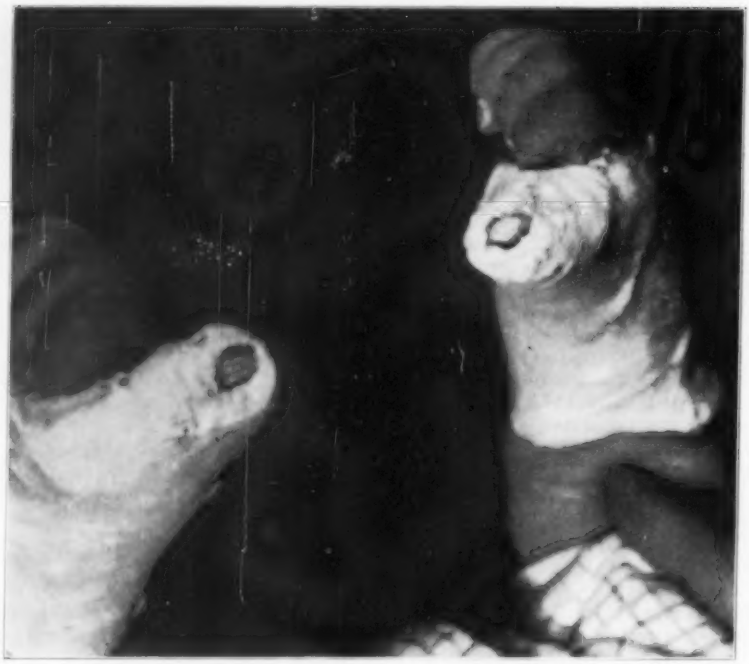

FIG. 4-A

Casts when first applied, the patient then being eleven weeks of age.

FIG. 4-B

Six months later, following plaster immobilization of one month's duration on the right hand and three months' on the left hand.

palm is interesting. The mother of C. F. (Case 2) exhibited abnormal mobility of her proximal thumb joints but had no other abnormality of her hands.

The period of immobilization in the first two cases was five and one-half to seven and

one-half months. In the most recent case, one to three months gave a good result. It is thought that plaster immobilization is most desirable in that it gives the most constant support. The casts must be changed each six to eight weeks to allow for growth. Associated flexion contractures of the fingers, when present, are treated simultaneously.

A trial period of plaster immobilization will show whether or not extensor tendons are present. If no extension returns after several months of plaster immobilization, tendon transfer to restore active extension is indicated.

SUMMARY AND CONCLUSIONS

Of the five cases of congenital flexion-adduction deformity presented in this report, all were bilateral except Case 3. The patient in Case 3 had a congenital absence of the left thumb. In each instance of the deformity, the thumb was firmly clasped beneath the flexed fingers and did not exhibit active extension. Three patients also had an associated tightness of the web space between the thumb and index finger. All the patients had abnormal mobility of the metacarpophalangeal joints of their thumbs.

In three of the patients, seen one to three months after birth (Cases 1, 2, and 5), plaster immobilization gave excellent results. In the fourth patient, seen at the age of two years (Case 4), a fair to good result was achieved after three months' immobilization. In another patient, seen at age nine (Case 3), a fair result was obtained by fusion of the metacarpophalangeal joint of the thumb.

Congenital flexion-adduction deformity of the thumb should be corrected by plaster immobilization in functional position at the earliest possible time, before permanent joint and tendon changes occur. If active extension does not return, tendon transfer is indicated to restore active extension to the thumb.

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DISCUSSION

Dr. George S. Phalen, Cleveland, Ohio: I was very interested to hear of Dr. Weckesser's experiences in treating five cases of congenital clasped thumb. He is most fortunate to have had the opportunity of seeing so many cases with this unusual congenital deformity. I am sure that very few of us here at this meeting can duplicate his experience.

One wonders why this anomaly is not observed more often. For the first few months of life, the thumb actually serves no useful purpose in the infant's existence. It is not until he learns to use the thumb in grasping that he has any good reason to raise his thumb out of his palm. All of us have observed how much of the time a normal infant keeps his thumbs tightly clasped in his palms.

It is easy to see how congenital adduction of the first metacarpophalangeal joint might be part of a generalized arthrogryposis. Four of the author's five cases might fall into this group. The ease and permanency of the correction of the deformity, however, would lead one to believe that congenital clasped thumb is not similar to an arthrogryposis.

I would like to ask Dr. Weckesser if he observed the fate of the soft-tissue bands in the first web in those cases in which an adequate correction of the deformity was obtained. Did these bands soften, stretch, or disappear entirely? Also, in the two cases requiring operative correction, was the contracture in the first web found to be due to a subcutaneous fibrous band or due to skin contracture only? If a subcutaneous fibrous band was found at operation, was it observed to be a thickened part of the normal palmar fascia, such as we

see in Dupuytren's contracture? If any fascial bands were removed in these two cases, were any histologic studies made of this tissue?

I would certainly agree with Dr. Weckesser that plaster immobilization is the best method of treating this deformity. The good results obtained with early treatments serve again to emphasize the importance of correcting all soft-tissue contractures as soon as possible before permanent joint contractures or bony deformities develop.

Dr. Arthur J. Barsky, New York, N. Y.: Dr. Weckesser stated that in four of his five cases flexion or extension deformities were present in joints other than those of the thumb. The cases in which the condition was not limited to the thumb joints alone belong, I believe, in the category of what is variously called arthrogryposis multiplex congenita, multiple articular rigidities, or, to use a term that is perhaps better, amyoplasia congenita.

Curiously enough, this same condition has been found in lambs, a circumstance which has provided additional data. There appears to be present a hereditary factor of a recessive nature.

Gilmour had the opportunity of autopsying a baby with hand involvement and found that *no extensor pollicis longus* was present. The muscles affected in this baby were much smaller than the normal due to an actual decrease in the number of fibers. There was a definite increase in the number of collagenous fibers in the endomysium and perimysium. In another case, Middleton found that the extensor pollicis longus was replaced by adipose tissue containing fibrous strands and remnants of muscle fibers.

Weak electrical response has been reported but not reaction to degeneration.

The belief has been expressed that stiffness of the joints is the primary cause of the limitation of motion. Although this fixity of the joints sometimes has the clinical appearance of a fibrous ankylosis, there is no definite evidence of inflammatory change. The joint fixity is *probably* largely due to disuse arising out of a lack of active and passive motion; with disuse one would expect the periarticular tissues and even the skin to become tight.

Middleton's observation on lambs indicates that the process is one of degeneration of formed and differentiated muscle fibers. There is no definite evidence as to the nature of the abnormality which causes the atrophy and degeneration of the already formed muscle fibers, but it is thought (by Gilmour) that the process is *not* dependent on external influences but is possibly dependent on an intrinsic genetic abnormality centered in the muscle cells.

We have had four cases of amyoplasia, three of which give a good idea of the gradations of the condition.

[A lantern slide was shown of the mildest case, in which involvement of only the index fingers of both hands was apparent. A second slide showed a case in which the wrist and elbow joint were affected, and a third slide showed involvement of practically all the joints of all four extremities.]

Dr. Weckesser has made an excellent point, one that bears emphasis, namely, that very early treatment by splinting will probably result in improvement if enough muscle fibers are left to function.

Dr. Weckesser (closing): In answer to Dr. Phalen's questions about the thumb-web contractures, I wish to state that the tight bands between the thumb and index finger seemed to remain essentially unchanged. In the two cases requiring surgery, the tight band was found to be due to skin contracture only. No subcutaneous bands were present.

Non-Operative Treatment of Lumbar Disc Syndrome

(Continued from page 936)

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MASSIVE OSTEOLYSIS (ACUTE SPONTANEOUS ABSORPTION OF BONE, PHANTOM BONE, DISAPPEARING BONE)

Its Relation to Hemangiomatosis *

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In a recently published study of two cases of disappearing bone, it was suggested that a vascular abnormality of some kind (angiomatosis) bears a direct relationship to this unusual disease of bone. The authors, Gorham, Wright, Shultz, and Maxon, described the presence of an overgrowth of small thin-walled blood vessels (angiomatosis), and advanced the hypothesis that the resulting active hyperaemia may disturb the normal balance between osteoclasts and osteoblasts, so that an excess of bone destruction over new-bone formation is produced.

One may search through the standard textbooks of medicine, surgery, orthopaedics, roentgenology, and pathology without finding a single reference to this unusual condition. Even *French's Index of Differential Diagnosis*, a storehouse of information on medical curiosities, fails to mention it. The most comprehensive discussion of the subject in English appeared in Coley's classical monograph, *Neoplasms of Bone*. This author stated that acute spontaneous absorption of bone is "A little understood and extremely rare condition", that it has been described also as "phantom bone" or "disappearing bone", and that only three cases had been reported before 1946. Coley presented a table of four published and three unpublished cases.

Not included in Coley's tabular list is No. 19, Table I, reported by Bickel and Broders as "Primary Lymphangioma of the Ilium". In discussing it separately, however, Coley remarked most significantly: "One is struck by the similarity of this case to others mentioned as examples of 'disappearing bone' or 'spontaneous absorption of bone' on every ground except that of the histology; in the other instances there was no suggestion of either an inflammatory or a neoplastic process whereas in the case of Bickel and Broders it appears to have been due to benign neoplasm of a type which has not been previously recognized as occurring in bone." Coley stated that there is nothing to suggest that these cases can be explained on a neoplastic, infectious, or metabolic basis. "The gross and microscopic features give us little assistance in explaining the nature of this obscure disease. Bone is apparently absorbed and replaced by fibrous tissue and no other specific features are presented."

Mouchet of Paris has long manifested a keen interest in this curious malady and with his associates has discussed it at length on several occasions before the *Académie de Chirurgie*. He has reported two cases in great detail. He was the first author to review the literature carefully and to speculate on the etiology of this baffling disease. From a study of eight published cases, he concluded that trauma, which is usually slight, does not play an important role in causation. Although the condition is confined to children and young adults, he noted that the disease is not modified by treatment for recalcification or by endocrine therapy. He rejected the theory of Leriche that the cause of localized osteolysis in these cases is active hyperaemia induced by trauma. Leriche has reported that, in post-traumatic osteolysis, periarterial sympathectomy produces an extraordinary curative effect. This operation was performed early in the course of No. 4, Table I, without benefit. Mouchet concluded that the last word had not been said as to the mechanism

* Presented in abstract form before the Sixty-seventh Session, Association of American Physicians, Atlantic City, New Jersey, May 4, 1954.

TABLE I

REVIEW OF CASES OF MASSIVE OSTEOLYSIS

No.	Authors	Age	Sex	History of Injury	Bones Affected *	Biopsy Findings	Follow-up Information
1	Jackson†, 1819	18	M	Fractured right arm three times.	Right humerus 3+	None.	Died 52 years after onset.
2	Römer, 1928	31	F	None.	Ramus of left mandible entirely absorbed; body reduced to a feather-like residue on left side 2+	None.	None.
3	Thoma, 1933	36	F	Not definite.	Mandible 3+ Maxilla 1+ Palatine 1+ Sphenoid 1+	Connective tissue and capillaries.	Died 10 years after onset. Operation for suspected parathyroid tumor.
4	Dupas, Badelon, and Daydé, 1936	12	M	Fracture of left hand by fall, and second fracture.	Left metacarpals I to IV 3+; V 2+ Carpal bones 3+ Index and middle finger — first phalanges 3+ Left radius and ulna 1+	Fibrous tissue rich in blood vessels.	Working Jan. 1, 1955, 25 years after onset (letter from Prof. Mouchet).
5	Sauvé, 1936	37	M	Two years after operation for hallux valgus.	Bases of all metatarsals 1+ Anterior tarsal bones 1+	None.	None.
6	Steenhuis and Nauta, 1936	45	F		Mandible has entirely disappeared 3+ Bone in upper jaws markedly affected 1+	Two biopsies reported as inflammation, not tumor, not Actinomyces.	Died. Metastatic abscesses, chest wall.
7	Simpson, 1937	14	F	Tripped over rope, falling on toes.	Left metatarsals III, IV, V 3+ Left tarsals 1+	"Marrow replaced by fibrous vascular tissue."	Able to work and cycle June 13, 1953, 25 yrs. after onset (letter from Simpson).
8	Mouchet and Rouvillois, 1937 (Originally Jacob, 1913)	12	F	Fall on left hip while jumping rope.	Left pubis 2+ Left ischium 2+ Left ilium 1+ Left femoral head 1+	None.	Marked deformity, unable to walk without corset, cane, and built-up shoe, but condition well stabilized 43 yrs. after onset (letter from Prof. Mouchet).

9	Leriche, 1937	Young man	M	Minor fracture of tibia after fall.	Tibia 2+	None.	None.
10	Radulesco, 1937	14	M	Contusion of wrist; 8 months later atrophy of end of radius.	Radius, lower end 1+ Carpal bones 1+	None.	None — impossible to trace.
11	Richard, 1937	51	M	Shell explosion, 1916.	Left femur 2+	None.	None — impossible to trace.
12	Jackman, 1939	21	M	Pain in hand after chopping wood.	Right third metacarpal 3+ Right third finger 3+	"Resembles fibrocystic disease."	Full work as gardener, Aug. 1952, 21 yrs. after onset (letter from Jackman).
13	Duval, 1939	58	F	Operation.	Tibia 1+ Fibula (lower third) 1+	None.	None.
14	Baccaglini, 1941	27	M	Contused right hand, bicycle accident, fracture.	Absence of all carpal bones, right hand, except scaphoid 2+, and lower third of right radius 1+	None.	None.
15	Mouchet and Simonin, 1943	8	F	Fell on stairway.	Left lower epiphysis humerus 1+ Left radius 1+ Left carpal bones 1+ Left metacarpals 1+ Left lower epiphysis radius 3+	None.	Stabilized after 16 yrs. (letter from Prof. Mouchet).
16	Branch, 1945	20	M	Pain in left shoulder after shooting rifle.	Left clavicle 3+ Left humerus 1+ Left ribs 1+ Thoracic vertebra 1+ Left scapula 1+	"Abundant vascular channels."	No change in x-ray 6½ yrs. later.
17	Nicod, 1945	15	F	Ski injury. Spontaneous fracture of ulna on rings in gymnasium.	Left radius 1+ Left carpal bones 1+ Left ulna 1+	Chronic inflammation, "*bourgeonnements vasculaires.*"	None.

TABLE I (*Continued*)

No.	Authors	Age	Sex	History of Injury	Bones Affected *	Biopsy Findings	Follow-up Information
18	King, 1946	11	M	Fall from bicycle, knee injury.	Left femur 2+	Hemangiomatosis (limb amputated).	Process arrested 12 yrs. after onset, Sept. 28, 1953. Patient to enter medical school (letter from King).
19	Bickel and Broders, 1947	5	F	None. Spontaneous limp developed 15 months earlier.	Left ilium 3+ Ischium 1+ Sacrum 1+ Lumbar vertebrae IV, V on left 1+	Primary lymphangioma of the ilium, later diagnosis (second biopsy) hemangioma.	Confined to wheel-chair. Condition arrested 10 yrs. after onset, Nov. 16, 1953 (letter from Dr. Fetterman).
20	Coley, 1949 (Smith, Murray, and Stout, 1954)	41	F	Tried to catch a falling child. Two weeks later, fractured clavicle lifting ice.	Right clavicle 3+ Right scapula 3+ First right rib 2+	Peculiar changes — no definite diagnosis.	Died 5 yrs. after onset. Pulmonary thrombosis and chronic endocarditis.
21	Lièvre, 1949 (Mialaret, 1953)	21	M	None. Pain in sternal area of 4 years' duration.	Sternum 2+ and several ribs 1+	Absorbed rib without definite or characteristic histopathological changes.	Not working. Condition critical 6 yrs. after onset, but still gets about (visit to Dr. Lièvre in Paris, July 8, 1953).
22	Amaral, 1950	Not given.	M	Nail in foot. Lymphangitis extending to thigh.	Right ischium 3+ Right pubis 3+ Right ilium 2+	None.	None.
23	Gorham, Wright, Shultz, and Maxon, 1954	16	M	Fracture of the clavicle in a fall.	Right clavicle 3+ Scapula 2+ Head of humerus 1+ Ribs 3+ Vertebrae 1+	Hemangiomatosis.	Died after 2½ yrs.
24	Gorham, Wright, Shultz, and Maxon, 1954 (Smith, Murray, and Stout, 1954)	40	M	Pain in right shoulder after playing handball and carrying heavy weight.	Right clavicle 2+ Right scapula 1+ Right humerus 1+	Vascular channels, mainly of lymphatic type.	Examination 5 yrs. after onset, Feb. 11, 1953. Working daily as accountant.

* 3+, 100 per cent. osteolysis; 2+, over 50 per cent.; 1+, slight to moderate osteolysis. † Ascribed to Jackson but actual author not verified.

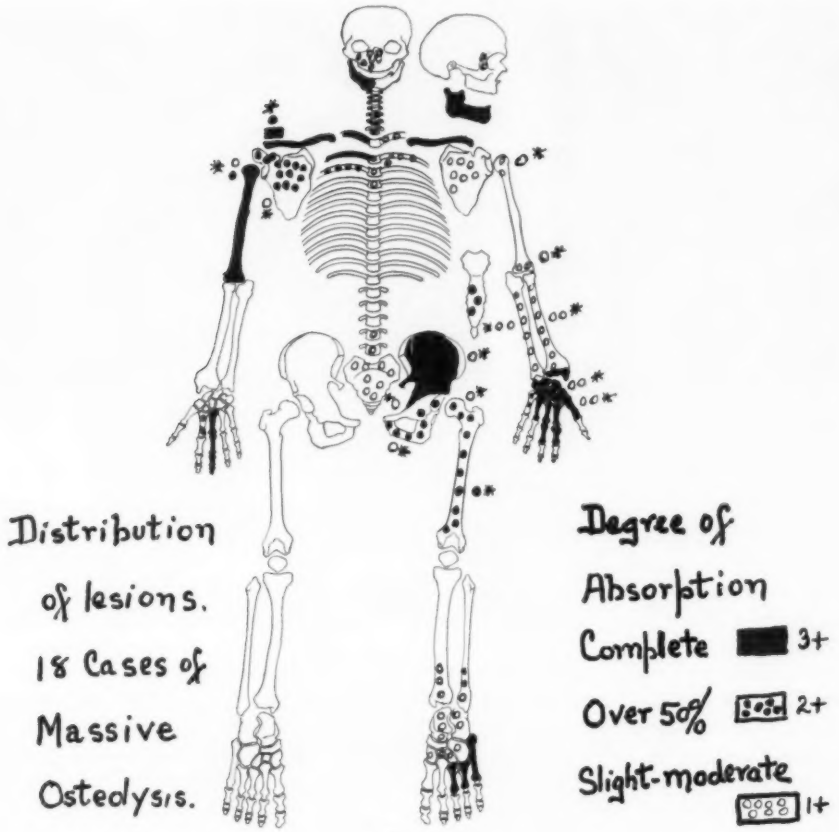

FIG. 1

Graphic chart of bones involved in lytic process. An asterisk adjacent to a bone indicates an additional case or cases. The degree of involvement in each of these extra cases is shown by symbols: Complete disappearance, 100 per cent. (3 +), is indicated by solid black; over 50 per cent. (2 +) by black dots; and slight to moderate involvement (1 +) by circles. For example, the right clavicle disappeared completely in two cases and over 50 per cent. vanished in a third case.

and the therapy of this type of osteolysis, which does not seem to be of hormonal origin and which, if it should be proved to be of traumatic origin, arises only as the result of insignificant trauma. He further stated that the day will come when some new, well observed facts, submitted to careful clinical examination and to complete laboratory investigation, will permit us to elucidate the causes of this singular osteolysis and to cure it.

Leger, Ducroquet, and Leger described a case of essential osteolysis involving the complete disappearance of the second phalanx in each of the last four fingers and complete disappearance of the distal segment of the first phalanx of the thumbs. Because of symmetrical involvement, intermittent numbness, tingling, and a pricking sensation in the fingers, as well as pallor of the right index finger and thumb, the authors considered the case to be of neurogenic origin. They discussed some twenty other cases of essential osteolysis from the literature. At least five of these were associated with chronic rheumatoid arthritis, similar to the case of Marie and Léri, reported in 1913 as *la main en lorgnette* or "opera-glass" hand. Leger, Ducroquet, and Leger also included in their review Nos. 4, 7, 8, 10, 11, 12, 13, 15, and 17 in Table I.

In conclusion, these authors stated that, without offering a satisfactory solution to

FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 1 (text). Depression over the site of the right clavicle, six months after fracture. (Reproduced, by permission, from Disappearing Bones: A Rare Form of Massive Osteolysis. Report of Two Cases, One with Autopsy Findings, by L. W. Gorham, A. W. Wright, H. H. Shultz, and F. C. Maxon. *The American Journal of Medicine*, **17**: 675, 1954.)

Fig. 2-B: Roentgenograms of the chest made sixteen months after fracture of the right clavicle, showing disappearance of the first two ribs and of the clavicle, as well as thinning of the scapula and of the humeral head on the right side.

the problem in pathology caused by such osteolysis, they were rather tempted to incriminate a nervous cause. It is quite evident that these authors believed that the same type of mechanism for dissolving bone is operative in the three classes of cases discussed: (1) Osteolysis associated with a possible infection, such as rheumatoid arthritis; (2) osteolysis associated with diseases of the central nervous system; and (3) the massive type of osteolysis with complete disappearance of bone. It is the third form of osteolysis with complete disappearance of bone which will be discussed in this paper. The authors believe this last form to be associated with hemangiomatosis. The argument for this will be developed in this paper.

Our present communication was stimulated first, by the fact that, in nearly every one of the reported cases in which biopsy was done, the writers described the histological picture as showing the presence of numerous blood vessels, and second, by the first report of a fatal case with biopsy and complete autopsy, in which the resemblance of the lesion to hemangioma was most compelling [12]. Reference to Table I will show the various descriptive terms employed by different authors in reporting the histological changes encountered, such as the following: "connective tissue and capillaries", "fibrous tissue rich in blood vessels", "marrow replaced by fibrous vascular tissue", "resembles fibrocystic disease", "abundant vascular channels". The purpose of this paper, therefore, was to collect all of the extant microscopic slides from the cases in which biopsy specimens had been obtained and to review and compare these carefully by personal examination. After persistent effort over a period of several years, it has been possible to assemble the original sections from a total of eight cases. We are deeply indebted to the various authors who placed this material at our disposal. Their names with a special acknowledgment will be found listed at the end of this paper. In six instances, no biopsy specimens had been obtained and in four cases the slides were destroyed by bomb damage during the second World War in France or in England. It was believed that only by comparing all of the actual original histological sections available could one determine whether or not a basic pathological lesion was present in cases of massive osteolysis.

The phenomenon of the extensive disappearance of an entire bone, such as the clavicle, scapula, or humerus, is quite distinct from the thinning of bone which occurs in atrophy from disuse. It also differs from the acute inflammatory atrophy associated with

FIG. 2-C

Fig. 2-C: Photomicrograph (× 26) of biopsy specimen obtained from the rib sixteen months after fracture of the right clavicle, showing only osteolysis.

Fig. 2-D: Photomicrograph (× 175) of autopsy specimen from vertebra, showing microscopic appearance of the bone marrow. Note exceedingly thin-walled capillaries distended with red blood cells.

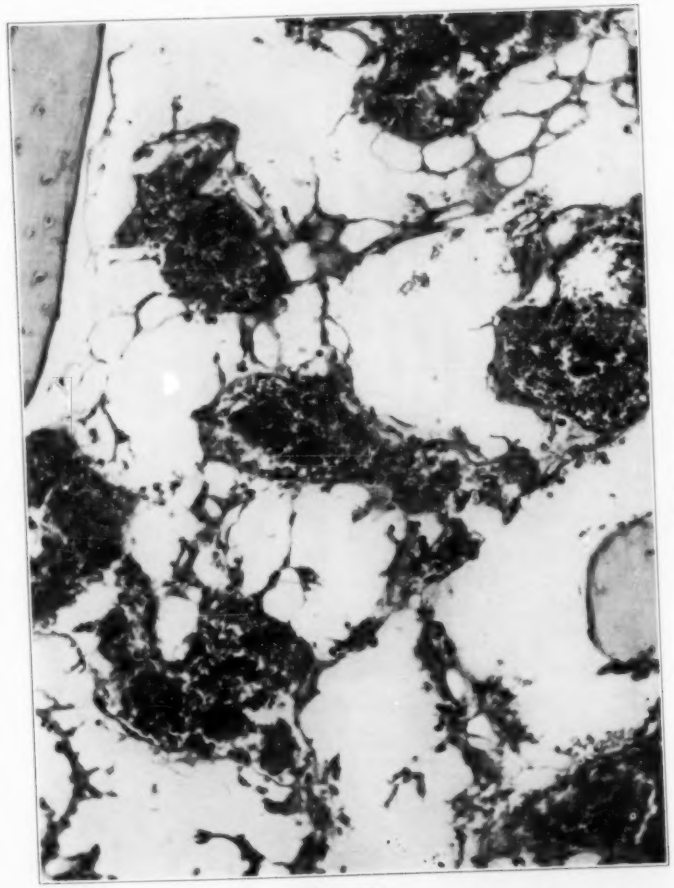

FIG. 2-D

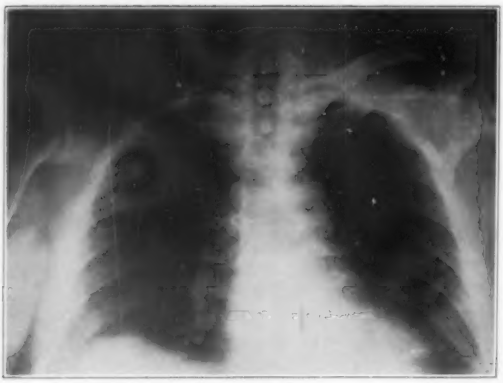

FIG. 3-A

Case 2 (text). Roentgenogram of chest showing disappearance of outer two-thirds of right clavicle. (Reproduced, by permission, from Disappearing Bones: A Rare Form of Massive Osteolysis. Report of Two Cases, One with Autopsy Findings, by L. W. Gorham, A. W. Wright, H. H. Shultz, and F. C. Maxon. *The American Journal of Medicine*, **17**: 678, 1954.)

trauma described by Sudeck and from lytic processes in bone due to tumor, hyperparathyroidism, and other known causes. Osteolysis of notable degree has been observed in rheumatoid arthritis, leprosy, malum perforans pedis, and congenital pseudarthrosis, but in these cases a considerable portion of the affected bone remains, and the disease does not lead to complete disappearance of a bone by concentric atrophy, with only a fibrous-tissue band left as a residuum.

A review of the sixteen cases collected from the literature by Gorham, Wright, Shultz, and Maxon, together with the two reported by them, is presented in tabular form (Table I). To these cases six additional cases from the literature have been added, making a total of twenty-four published reports. The clinical and roentgenographic features are here summarized.

Reference to Table I permits one to make certain general statements concerning disappearing bones. The disease usually occurs in childhood; thirteen patients were twenty-one years of age or under. The two sexes were about equally affected, there being fourteen males and ten females. Trauma, usually of rather mild degree, occurred in fifteen cases. The disability which develops is generally partial and there is slow progressive absorption of bone over a period of years. Stabilization occurs eventually in nearly all instances. The milder cases show the absorption of part of a single bone, while the severer cases progress until almost all of the osseous tissue of one or more bones has disappeared, with only a fibrous band left as a residuum. Regeneration of bone to any notable extent has not occurred.

The lytic process is not limited to a single bone, such as the clavicle, but may involve almost any bone in the skeleton in a particular case. The distribution of lesions in eighteen cases is shown in Figure 1, and the degree of involvement is graphically indicated. The left clavicle disappeared completely in one instance. The humerus, mandible, pubis, ischium, and ilium were completely absorbed in different cases. Involvement of lesser degree appears widely scattered through the skeleton.

Follow-up studies show six patients working five to twenty-five years after onset; three who are totally disabled six to forty-one years after onset; five who have died; and nine who cannot be traced. The causes of death were: one from old age, two from the disease itself or its complications, and one after operation for suspected tumor of the parathyroid.

There has been no agreement among pathologists as to the diagnosis of this condition and, as previously stated, the histological sections from the following eight cases were reviewed in order to throw more light on this question.

CASE REPORTS

CASE 1 (Gorham, Wright, Shultz, and Maxon; Table I, No. 23). A sixteen-year-old boy fractured his right clavicle. Six months later, a visible depression in the bone was noted (Fig. 2-A). Over a period of two years, the clavicle and the first two ribs disappeared completely, while partial absorption of the third rib, scapula, humeral head, lower cervical, and upper thoracic vertebrae occurred (Fig. 2-B). Death followed the development of a hemorrhagic effusion in the right chest, which became chylous. Biopsy of the rib early in

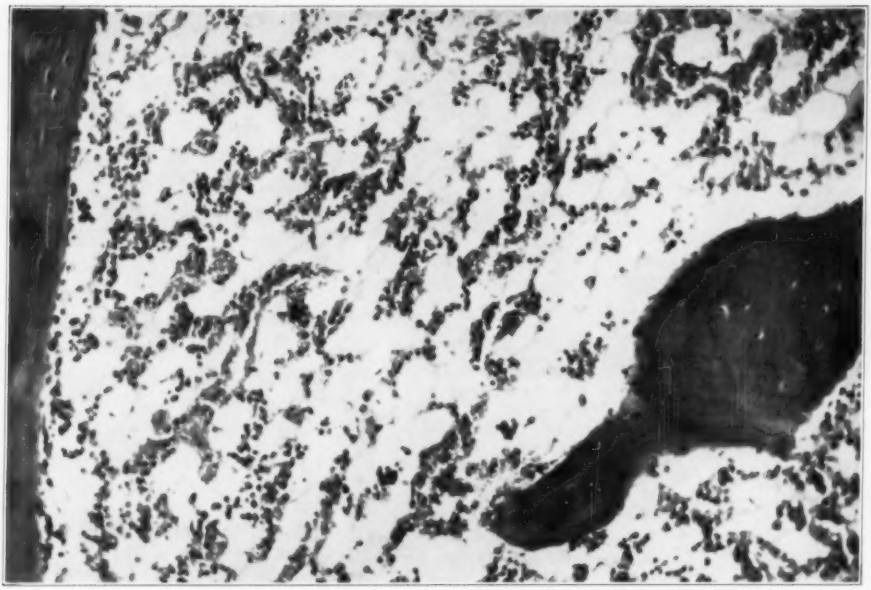

FIG. 3-B

Photomicrograph (× 120) of biopsy specimen obtained from the remaining fragment of the right clavicle, showing widened marrow spaces and a considerable number of exceedingly thin-walled capillaries, with normal endothelial lining cells and red blood cells.

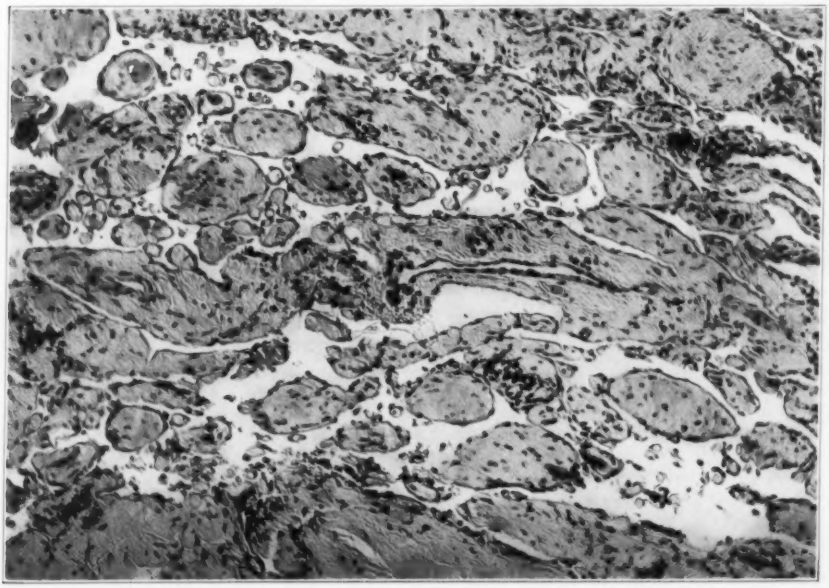

FIG. 3-C

Photomicrograph (× 120) of biopsy specimen obtained from the tissue replacing the vanished right clavicle, showing innumerable freely anastomosing capillary spaces lined by swollen prominent endothelial cells.

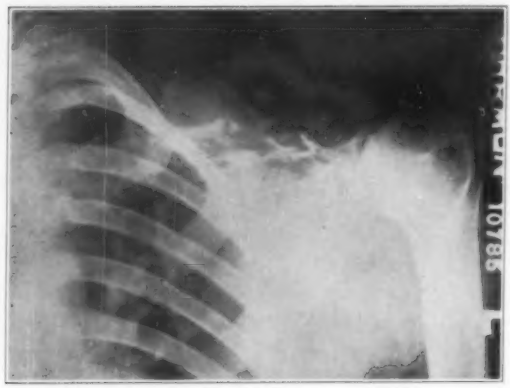

FIG. 4-A

Case 3 (text). Roentgenogram of the chest made one month after injury, showing disappearance of the left clavicle and rarefaction of the scapula, humerus, ribs, and thoracic vertebrae. (Reproduced, by permission, from Acute Spontaneous Absorption of Bone. Report of a Case Involving a Clavicle and a Scapula, by H. E. Branch. *The Journal of Bone and Joint Surgery*, **27**: 707, Oct. 1945.)

the illness showed extensive osteolysis with questionable thin-walled blood vessels. The true nature of the lesion was not recognized (Fig. 2-C). Autopsy finally led to the diagnosis of hemangiomatosis.

The striking features in this case are shown in the microscopic sections of ribs and vertebrae (Fig. 2-D). They consisted essentially of a marked proliferation of thin-walled capillaries, which were filled with red blood cells. The bony trabeculae were thin but not otherwise remarkable. In the tissue replacing the bones which had vanished, there was fibrosis and cellulitis, but no evidence of angiomatosis.

CASE 2 (Gorham, Wright, Shultz, and Maxon; Smith, Murray, and Stout; Table I, No. 24). In a man, forty-four years old, there was gradual spontaneous disappearance of the outer two-thirds of the right clavicle (Fig. 3-A). The diagnosis of the biopsy specimen was at first in doubt, and the question of possible hemangio-endothelioma was considered.

In reviewing the microscopic sections of this case, two types of lesion were encountered: (1) Tissue taken from the remaining fragment of clavicle showed the same features as in Case 1—that is, very thin-walled capillaries filled with red blood cells scattered through the widened marrow spaces (Fig. 3-B); and (2) tissue from the site of the vanished part of the clavicle was everywhere infiltrated by freely anastomosing vascular spaces lined by prominent endothelial cells. The lumina were empty (Fig. 3-C). This vascular proliferation extended outward between adjacent striated muscle fibers. Actively proliferating anastomosing vessels of this type, with swollen endothelial cells, characterize hemangio-endothelioma.

CASE 3 (Branch; Table I, No. 16). A twenty-year-old soldier complained of shoulder pain after rifle practice. One month later a roentgenogram revealed complete disappearance of the left clavicle with involvement of the scapula, humerus, ribs, and thoracic vertebrae (Fig. 4-A). A second x-ray made six and one-half years later showed the same extensive involvement. In the original report, no definite diagnosis was made, although "abundant . . . vascular channels" were noted in the slides from biopsy of the scapula.

In re-examining these slides, we found innumerable thin-walled capillaries both in the marrow spaces of the bones and in the tissues which replace the bones. Some of these capillaries were dilated and all were filled with red blood cells (Fig. 4-B). A second section from which bone had entirely disappeared showed only a group of blood vessels (Fig. 4-C).

CASE 4 (Bickel and Broders; Table I, No. 19). In a five-year-old girl a spontaneous limp developed in September 1942. Fifteen months later, in December 1943, roentgenograms showed the complete disappearance of the left ilium, and the process extended to the pubis, ischium, sacrum, and to the fourth and fifth lumbar vertebrae (Fig. 5-A). The case was reported in 1947 as a primary lymphangioma of the ilium. In 1948, approximately five years after the first biopsy, a second biopsy was performed in another clinic and at that time it was considered to be hemangioma (Fig. 5-D). Roentgenograms made in 1948 and 1953, five and ten years after the first roentgenograms, showed extensive and progressive concentric atrophy of the left femur (Fig. 5-C).

On re-examination, a microscopic section from the acetabulum showed, adjacent to the cartilage, marked vascular proliferation consisting of a few capillaries which contained red blood cells and many dilated empty endothelium-lined spaces (Fig. 5-B). These may

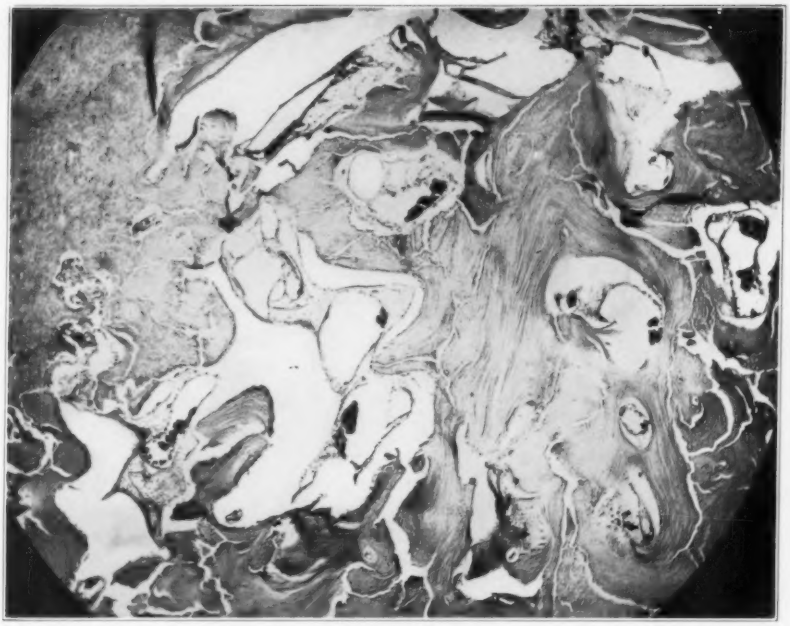

FIG. 4-B

Photomicrograph (× 37.5) of biopsy specimen obtained from scapula, showing numerous widely dilated capillaries almost filling the marrow spaces. The lacunae in most of the trabeculae are empty, indicating necrosis. There is no evidence of inflammation. (By permission of Major Lent C. Johnson.)

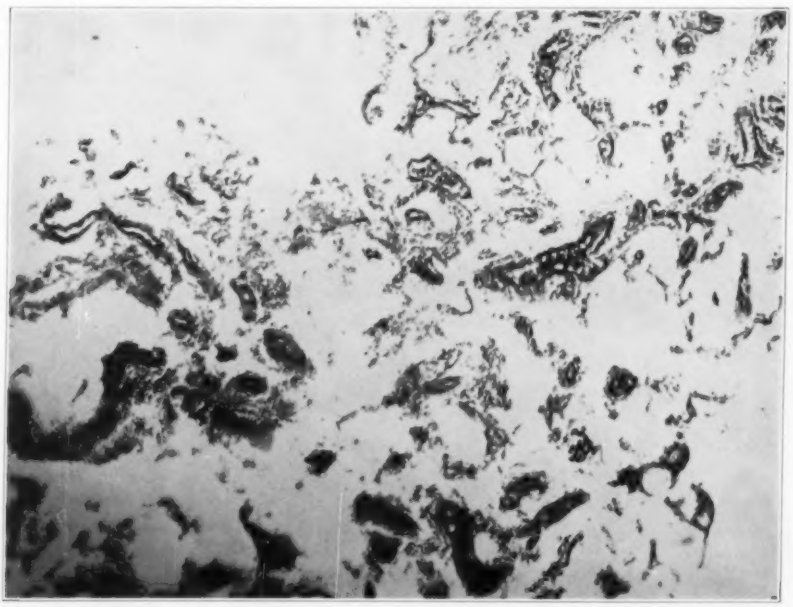

FIG. 4-C

Photomicrograph (× 47.5) of biopsy specimen obtained from the site of the vanished clavicle. No trace of bone is found; only loose-textured fibrous tissue containing many thin-walled capillaries filled with red blood cells remains. (By permission of Major Lent C. Johnson.)

FIG. 5-A

Case 4 (text). Roentgenogram of the pelvis made fifteen months after development of a spontaneous limp. Note the complete disappearance of the left ilium, with involvement of the pubis, ischium, sacrum, and the fourth and fifth lumbar vertebrae. (Reproduced, by permission, from Primary Lymphangioma of the Ilium. Report of a Case, by W. H. Bickel and A. C. Broders. *The Journal of Bone and Joint Surgery*, **29**: 517, Apr. 1947.)

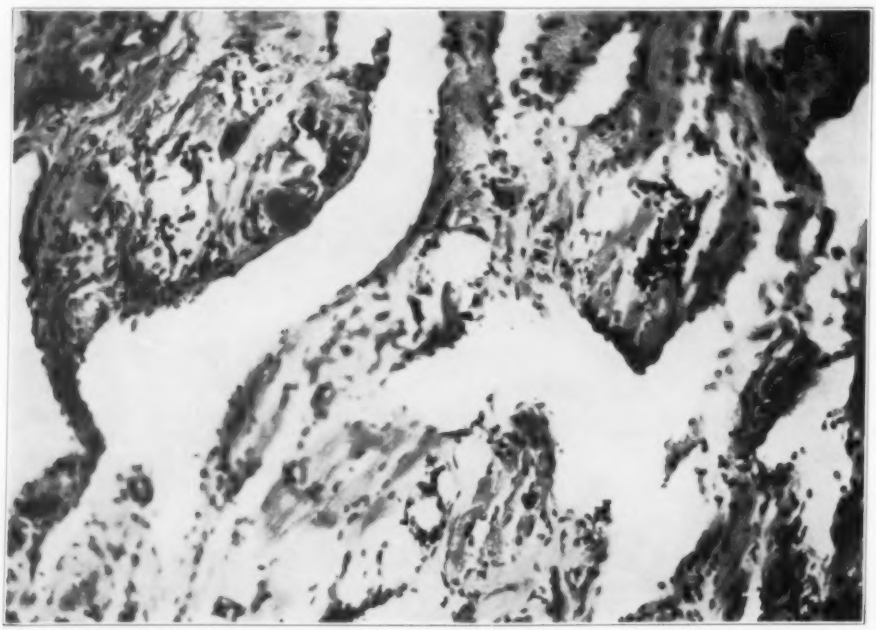

FIG. 5-B

Fig. 5-B: Photomicrograph (× 175) of a biopsy specimen of tissue adjacent to the acetabulum, showing dilated vascular spaces. (By permission of the Mayo Clinic.)

FIG. 5-C

Roentgenogram of the pelvis made ten years after the first roentgenogram, showing progression of concentric disappearance of bone in the left femur. There is no evidence of regeneration. (By permission of Dr. George H. Fetterman.)

be either blood or lymphatic spaces. They extended outward into the adjacent fat and striated muscle. On re-examination of the second biopsy specimen, taken from the site of the vanished ilium, freely anastomosing vascular spaces lined with endothelial cells were noted (Fig. 5-D). It was believed, upon review of the sections, that the lesion might be interpreted either as a hemangioma or as a lymphangioma.

CASE 5 (Coley; Smith, Murray, and Stout, Table I, No. 20). A woman, forty-one years old, first complained of slight temporary pain in her right shoulder when she suddenly moved her arms to prevent a child from falling out of a chair. Two weeks later, while she was lifting a cake of ice, severe pain occurred in the right clavicle, and roentgenograms showed a fracture. Fourteen months later there was recurrence of shoulder pain. Roentgenograms then revealed the surprising absence of the lateral two-thirds of the right clavicle (Fig. 6-A). By the end of the next four years, the clavicle had entirely disappeared, most of the scapula

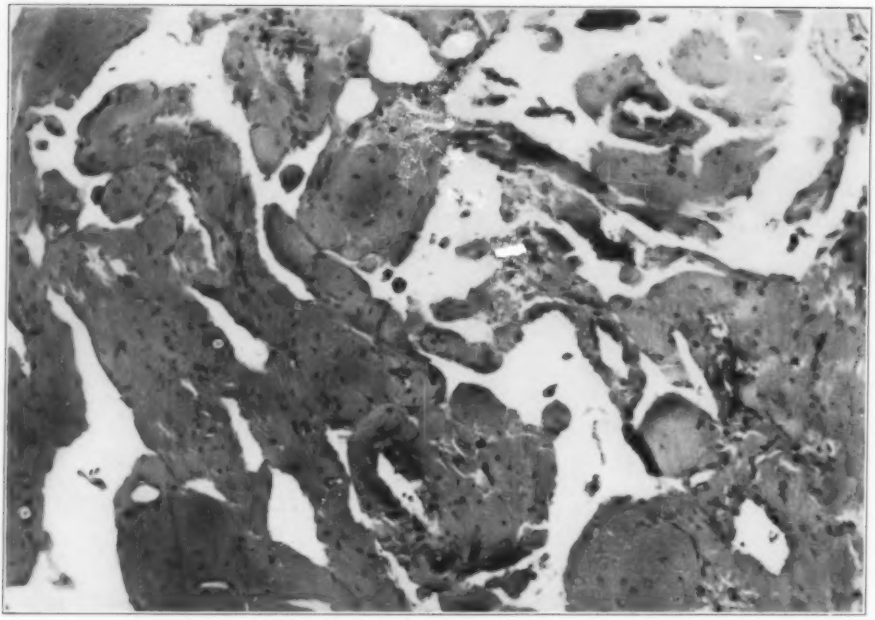

FIG. 5-D

Fig. 5-D: Photomicrograph (×120) of biopsy specimen obtained from the pelvis five years after the first biopsy specimen, showing tissue occupying the site of the vanished ilium. Note the freely anastomosing vascular spaces lined with endothelial cells. (By permission of Dr. George H. Fetterman.)

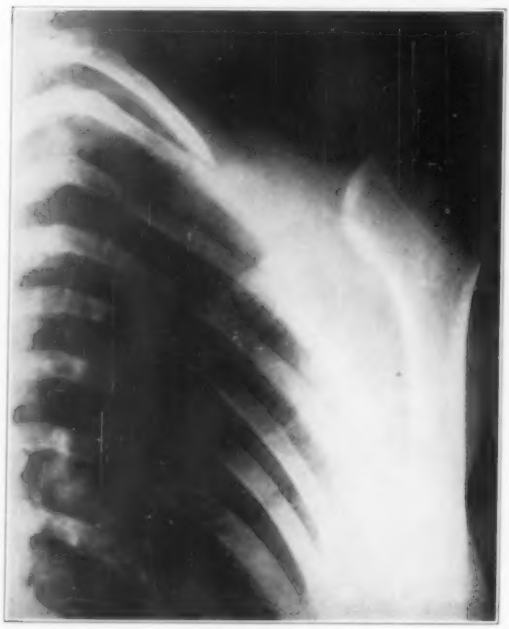

FIG. 6-A

FIG. 6-A: Case 5 (text): Roentgenogram of the chest, showing disappearance of the outer half of the right clavicle.

Fig. 6-B: Photomicrograph (× 175) of a biopsy specimen obtained from the site of the vanished right clavicle. Note the thin-walled dilated capillaries filled with red blood cells. (By permission of Dr. F. M. Smith, Dr. C. R. Murray, and Dr. A. P. Stout.)

Fig. 6-C: Photomicrograph (× 175) of a biopsy specimen obtained from the site of the vanished right clavicle in another area. Note the freely anastomosing vascular spaces lined by swollen endothelial cells, in this instance without red blood cells in the lumina. (By permission of Dr. F. M. Smith, Dr. C. R. Murray, and Dr. A. P. Stout.)

had been absorbed, and the first rib on the right side had begun to disappear. The original biopsy was not diagnostic.

On re-examination, we found that the affected bones showed a marked increase in the capillaries of the marrow spaces. Many were dilated and all were filled with red blood cells (Fig. 6-B). The maximum increase in dilated capillaries was seen where only traces of bone remained. The tissues which occupied the site of the van-

FIG. 6-C

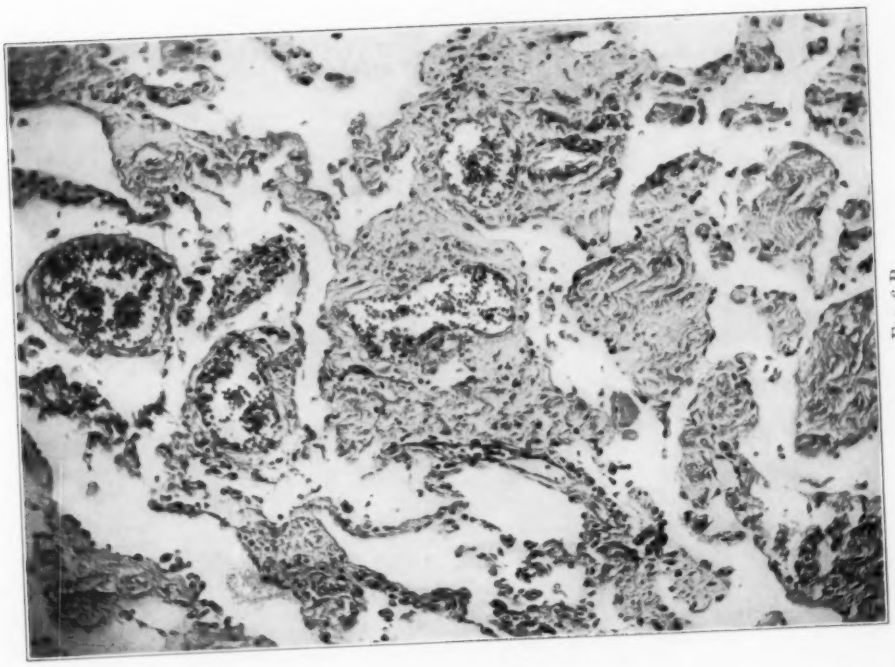

FIG. 6-B

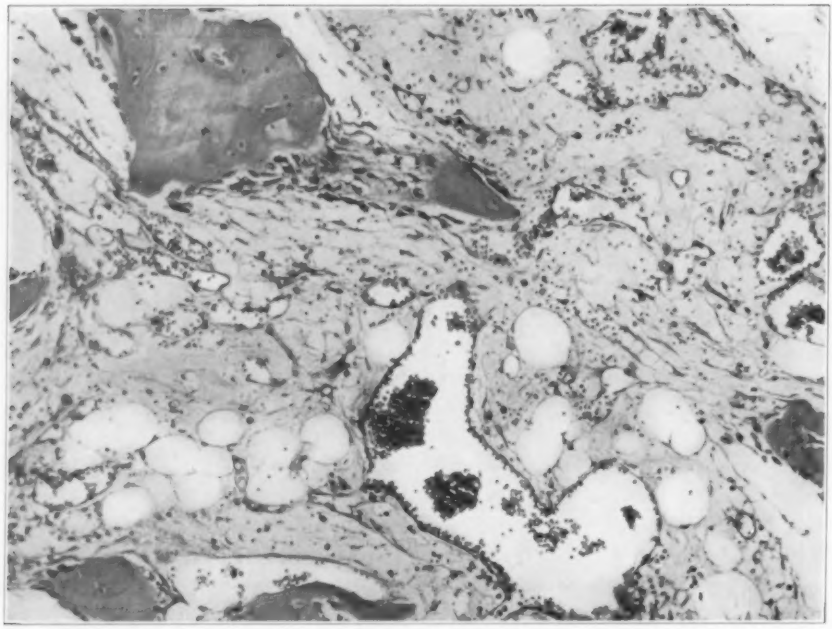

FIG. 7

Case 6 (text). Photomicrograph (× 155) of biopsy specimen from the left femur, showing numerous large and small capillaries with red blood cells in the widened marrow spaces. (By permission of Dr. D. J. King and Dr. R. C. Horn, Jr.)

ished bone at autopsy were honeycombed by a marked proliferation of empty vascular spaces which freely anastomosed and were lined with swollen endothelial cells (Fig. 6-C). The appearance simulates that of hemangio-endothelioma.

CASE 6 (King; Table I, No. 18). An eleven-year-old boy injured his knee. Roentgenograms showed the partial disappearance of the femur. A tumor was suspected and the limb was amputated. A diagnosis of hemangiomatosis was first suggested by one of us (A.P.S.) in 1946.

Re-examination of the sections taken from the lower end of the femur showed a widening of the marrow spaces and a proliferation in them of numerous capillaries, the majority of which contained red blood cells. A number of them were dilated (Fig. 7).

CASE 7 (Thoma; Table I, No. 3). A woman, thirty-six years old, with no definite history of injury, complained of pain in her jaw. Roentgenograms showed total absorption of the mandible, with extension to the maxilla and to the palatine and sphenoid bones. No definite diagnosis was made, but "connective tissue and capillaries" were noted in the biopsy specimen of the maxilla.

Re-examination of the slide showed only a small amount of the maxillary bone. There had been a marked proliferation of thick-walled vessels, some of which appeared to be arterioles and venules in the gum which impinges upon the alveolar process. Most of these contained few red blood cells or none. In only one marrow space did dilated thin-walled capillaries filled with red blood cells appear (Fig. 8).

CASE 8 (Lièvre; Table I, No. 21). A man, twenty-one years old, complained of pain in the sternal area.

Fig. 8: Case 7 (text). Photomicrograph (× 175) of biopsy specimen obtained from the maxilla, showing marked proliferation of rather thick-walled blood vessels. (By permission of Dr. K. H. Thoma.)

Fig. 9: Case 8 (text). Photomicrograph (× 175) of biopsy specimen obtained from sternum and adjoining rib. The section shown is from the site of the defect in the sternum, showing dilated capillaries filled with red blood cells. (By permission of Dr. J. A. Lièvre.)

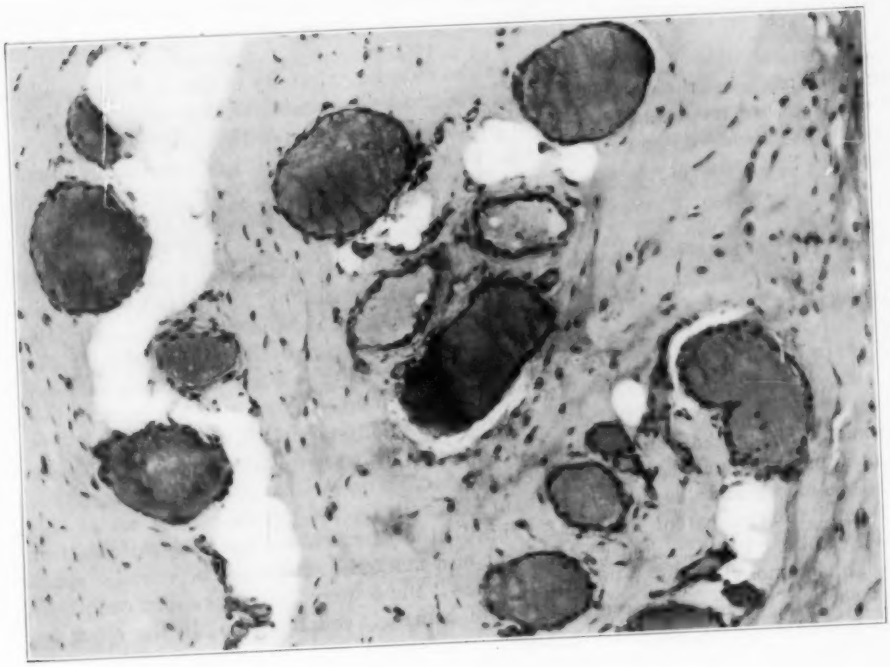

FIG. 9

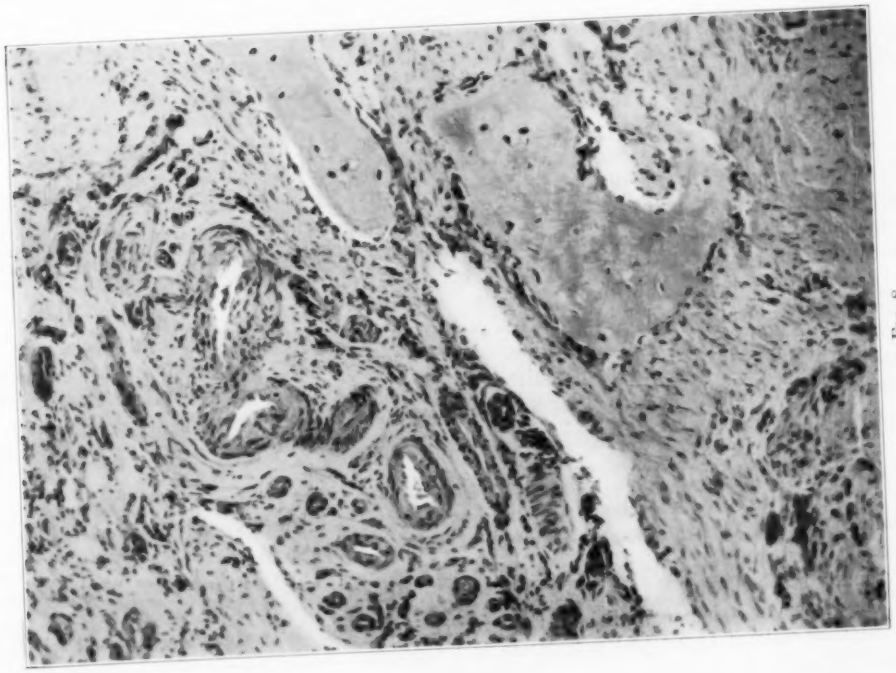

FIG. 8

Roentgenograms showed absorption of part of the sternum and of the ends of several ribs. The biopsy report was recorded as showing absorption of ribs without diagnostic pathological changes.

Re-examination of the sections from the anterior extremity of the eighth rib and of the tissue replacing the sternum showed a considerable number of large capillaries, most of which were distended and filled with red blood cells. In one section, the vascular spaces lay in dense fibrous tissue and were empty. The lining endothelial cells were normal and there was little tendency to anastomose (Fig. 9).

DISCUSSION

The foregoing microscopic findings reveal a striking similarity of the histological picture in every instance. The intensity of the vascular abnormality, however, varied considerably from one case to another. A study of these eight cases seems to show that there occurs first within the affected bones a marked increase in the number of capillaries, which are found to be dilated and filled with red blood cells when the bone is removed. This engorgement may be due either to obstruction to outflow or to hyperaemia from increased inflow of arterial blood — it is not possible to determine this from the biopsy specimens. The mechanism by which the bony trabeculae are demineralized and absorbed is not apparent from a study of the sections, since no osteoclasts can be recognized.

It is of considerable interest that, in Cases 2 (Fig. 3-C), 4 (Fig. 5-B), and 5 (Fig. 6 C), and to some extent in Case 8 (Fig. 9), the *fibrous tissue replacing the sites* from which the bone has vanished was the seat of a marked proliferation of vascular spaces which anastomosed freely and which, in Cases 2 and 5, were lined by swollen endothelial cells, so that the process resembled that of hemangio-endothelioma. In the other two cases (Cases 4 and 8), the endothelial cells were normal and the process might be either that of hemangioma or of lymphangioma. In Case 8, most of the vessels in the replacing fibrous tissue were filled with red blood cells; in Case 3 (Fig. 4-B), all of the vessels were filled with red blood cells; in Case 7 (Fig. 8), the microscopic section did not show the replacing tissue and in Case 1, aside from an inflammatory reaction, the replacing tissue did not show any excess vascular proliferation.

Since the evidence in these cases is somewhat conflicting, it is necessary to exercise caution in suggesting an interpretation. It would seem that, when the capillary proliferation within the marrow spaces has resulted in the complete removal of the affected bone, the vessels usually do not disappear but remain either as a vascular growth closely resembling that found within the marrow spaces, or as a spongelike meshwork of freely anastomosing vascular spaces without red blood cells. In only one instance did the vessels disappear entirely.

This whole process does not resemble the formation of ordinary hemangiomata in bones. These localize and do not spread, they may destroy bone but never dissolve it completely, and they show regeneration. The process simulates the proliferation of capillaries observed in the soft tissues distal to congenital arteriovenous fistulae. The term "hemangiomatosis" has been used by one of us (A.P.S.) to describe that proliferative process and it seems properly applicable to that described here.

CONCLUSIONS

1. There now exists the basis for a new syndrome which is supported by a remarkable similarity of clinical and roentgenographic findings in twenty-four cases, and by an equally convincing similarity of the histological picture in eight of these, which we have personally studied.

2. However it is accomplished, the progressive osteolysis is always associated with an angiomatosis of blood and sometimes of lymphatic vessels, which seemingly are responsible for it.

3. A discussion of the possible mechanism involved is outside the province of this paper. Whether massive osteolysis occurs as the direct result of active hyperaemia, of mechanical causes, of slight changes in pH, or from other causes cannot be established at the present time.

NOTE: We wish to express our gratitude and deep appreciation for the valuable cooperation of the following in furnishing the original biopsy material and roentgenograms of the cases listed:

F. M. Smith, M.D., C. R. Murray, M.D., and A. P. Stout, M.D., Columbia University, New York, N. Y. (Cases 2 and 5);

Major Lent C. Johnson, Armed Forces Institute of Pathology, Washington, D. C. (Case 3);

W. H. Bickel, M.D., and John R. McDonald, M.D., Mayo Clinic, Rochester, Minnesota (Case 4);

George H. Fetterman, M.D., Children's Hospital, Pittsburgh, Pennsylvania (Case 4);

David J. King, M.D., Wilmington, Delaware, and Robert C. Horn, Jr., M.D., University of Pennsylvania, Philadelphia, Pennsylvania (Case 6);

Kurt H. Thoma, D.M.D., Boston, Massachusetts (Case 7);

Dr. J. A. Lièvre, Paris, France (Case 8).

The willingness of these physicians and surgeons to furnish us with all available information, including original x-rays and biopsy material, has made this study possible.

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THE NATURAL HISTORY OF PIGMENTED VILLONODULAR SYNOVITIS OF TENDON SHEATHS

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"Giant-cell tumor of tendon sheath", familiar to orthopaedists as a firm nodular swelling most commonly occurring in the palmar aspect of the fingers and hand, has, in recent years, had increasing mention as "pigmented villonodular tenosynovitis", thereby creating confusion in the minds of clinicians who had associated this terminology with a lesion encountered in the knee and occasionally in other major joint cavities.

That the well defined tumor-like masses arising from tendon sheaths might be related to the pigmented villous lesions of the synovial membrane of large joints has been slow to receive universal acceptance.

An analysis of the main clinical and pathological features of this lesion and of its relationship to the pigmented villonodular lesions of large synovial surfaces has been made possible through the opportunity of studying thirty-four examples of the condition received in the Department of Surgical Pathology, Toronto General Hospital, between 1946 and 1953, together with a much smaller group of the more extensive lesions of knee joints.

Twenty-six of the thirty-four tendon tumors were in women. This agrees with the sex incidence in other published reports.

The hand was the site of occurrence in thirty-one instances. Thirty lesions were in the fingers, and one was in the palm. In one patient the tendon sheaths of two fingers were affected. The remaining three cases were in the foot. Of these, two were in the ankle region. All fingers were involved with approximately equal frequency, except for the ring finger, which was the site in only one case.

The age distribution was from eighteen to seventy years, with no significant predominance in one age group.

In only five cases was the tissue received in the department with a clinical diagnosis of pigmented villonodular tenosynovitis.

In twelve cases follow-up information was available at periods from one to six years after removal. Nine patients were free of recurrence. Three patients had recurrences three or four years after removal of the original lesion; one of these was free of the lesion three years subsequent to the second removal.

In those cases in which a history was available, a small painless lump or swelling of several months' or years' duration was the usual complaint. One mass had undergone a recent rapid increase in size, and another caused pain upon certain movements of the hand. Interference with movement is an occasional symptom, but none of the patients in this group complained of this difficulty.

PATHOLOGICAL FEATURES

Grossly, the lesions from the finger rarely exceeded two to three centimeters in diameter. They were firm, fibrous, often lobulated nodules enclosed in an incomplete capsule. The cut surface varied in color from grayish white through yellow to a deep reddish brown. Fine trabeculations originated from the capsule and transected the substance of the mass in a roughly radiating pattern (Fig. 2-B).

The synovectomy specimens, on the other hand, exhibited a wide range of changes, starting with thickening and pigmentation and progressing through granularity to even-

FIG. 1

Photomicrograph (× 15) showing lobular pattern and partial encapsulation of tendon-sheath tumors.

tual papillary formation. The papillary outgrowths became shorter, more blunted, and finally fused to assume the form of a lobulated mass generally indistinguishable from those arising from tendon sheaths. Occasionally several such masses were present in some of the larger synovectomy specimens.

The variation in the gross appearance of the two lesions may be related to their different physical environments. Exophytic growths, occurring in the relatively capacious synovial pockets at the margins of articular joint surfaces, maintain for a time a truly villous pattern. With continued enlargement the villi fill the available space, are progressively crowded, and finally fuse to produce nodular masses which often approximate in size the tenosynovial lesions.

Proliferations of the synovial lining of tendon sheaths, on the other hand, are continuously subjected to the shearing movements of the tendons in what is a potential space only. They fuse earlier and are forced away from the tendon into the sheath tissues, or, on occasion, may erode adjacent bone. In the latter circumstance, they may assume an unduly ominous appearance. The earliest stage of the tendon-sheath lesion is rarely seen by the pathologist, since it is only after the nodule has attained a size sufficient to constitute an inconvenience that the patient seeks a surgical opinion.

MICROSCOPIC CHANGES

The earliest change in the knee joint was thickening of the synovial membrane (Fig. 2-A). This was the result of piling up of cells of the synovial lining, which swell and increase in number. At this early stage many of these cells contained pigment, probably derived from blood. In addition, focal collections of rounded and polyhedral cells were found. With further progression, the proliferation of synovial tissues resulted in the formation of villous processes. These were covered by a prominent layer of synovial cells and possessed a stroma of loose connective tissue also containing pigment. The villi tended

to fuse with varying degrees of completeness, to form clefts and nodules, the latter being first microscopic in size but later grossly visible (Fig. 2-B). The earliest changes were rarely seen in tendon-sheath lesions, but from the stage of fusion of villi, the subsequent

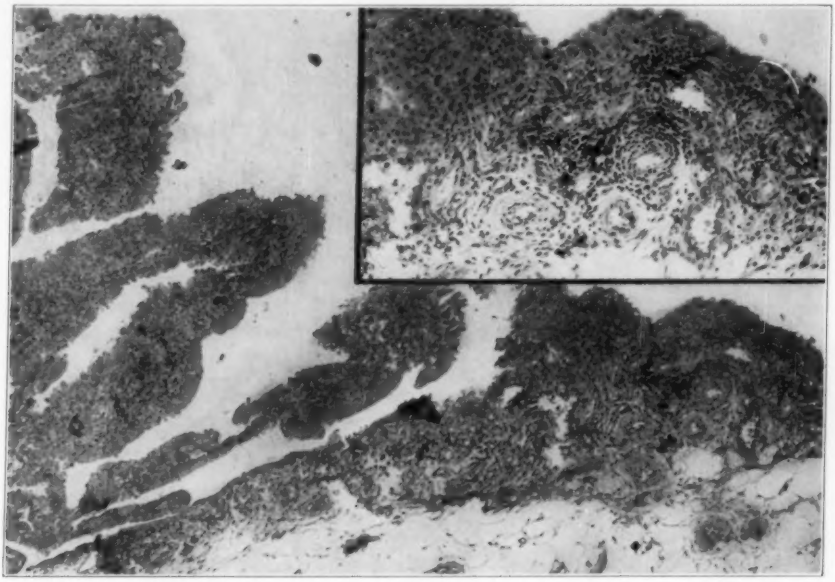

FIG. 2-A

Photomicrographs (× 36; inset × 105) showing synovial thickening with early villous formation in a lesion occurring in the knee joint.

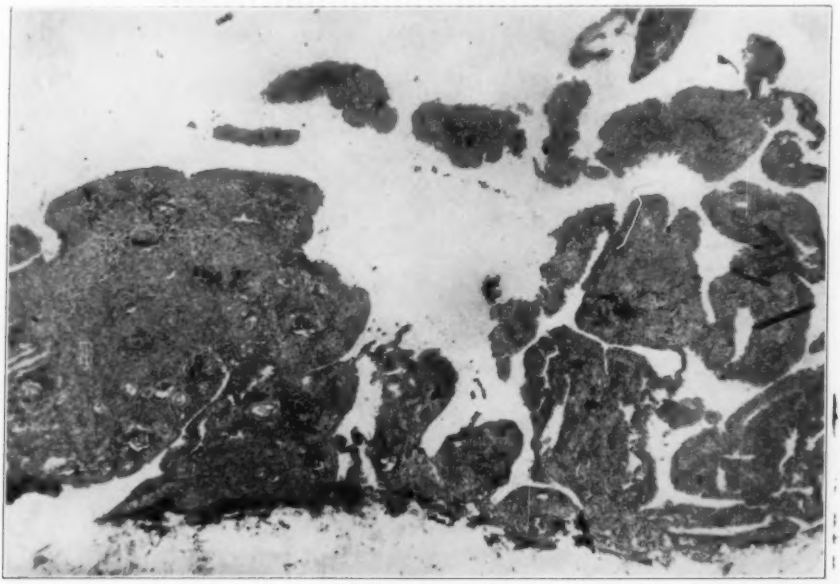

FIG. 2-B

Photomicrograph (× 40) showing early nodule formation in a lesion occurring in the knee joint.

course of events was identical in lesions from both knee joints and tendon sheaths.

In the second or cellular stage in the tendon sheath, a nodular pattern was well es-

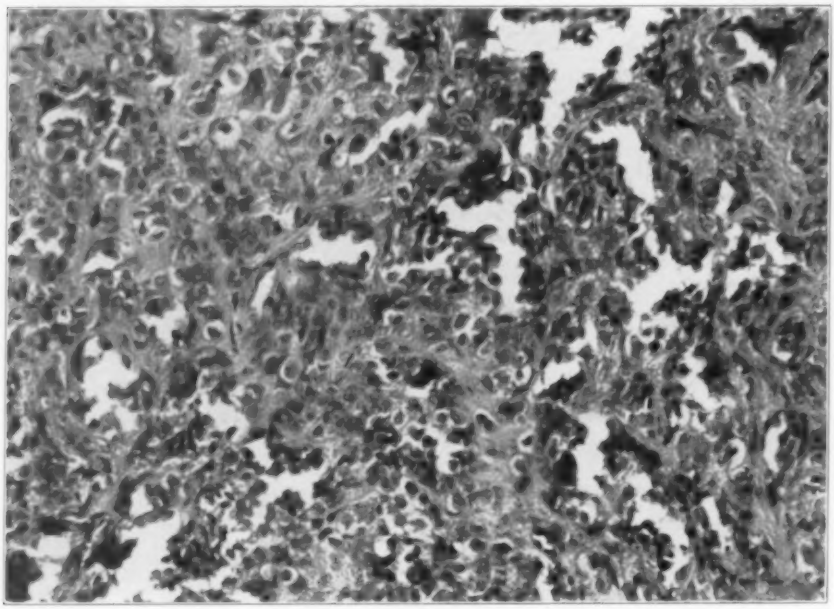

FIG. 3

Photomicrograph (× 174) showing synovial clefts in a tendon-sheath lesion.

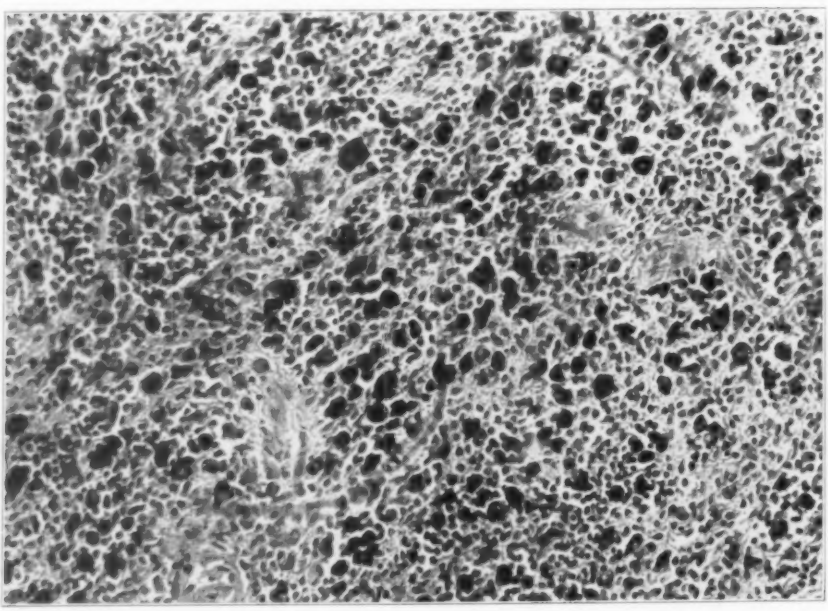

FIG. 4

Photomicrograph (× 160) showing pigment-filled macrophages in a tendon-sheath lesion.

tablished (Fig. 1). Fusion of villi produced synovium-lined clefts (Fig. 3). Fusion and enlargement of nodules resulted in the formation of an incomplete compression capsule

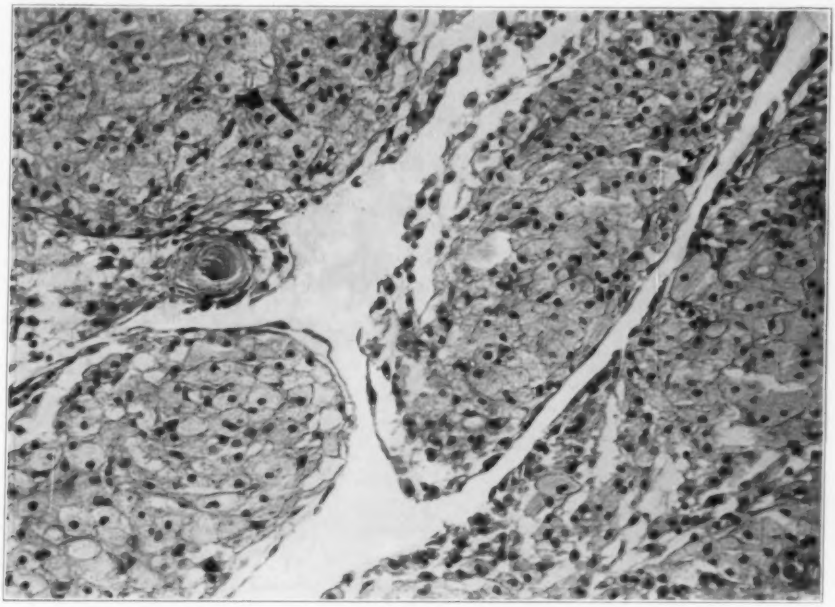

FIG. 5

Photomicrograph (× 170) showing lipid-filled macrophages about synovium-lined clefts in a tendon-sheath lesion.

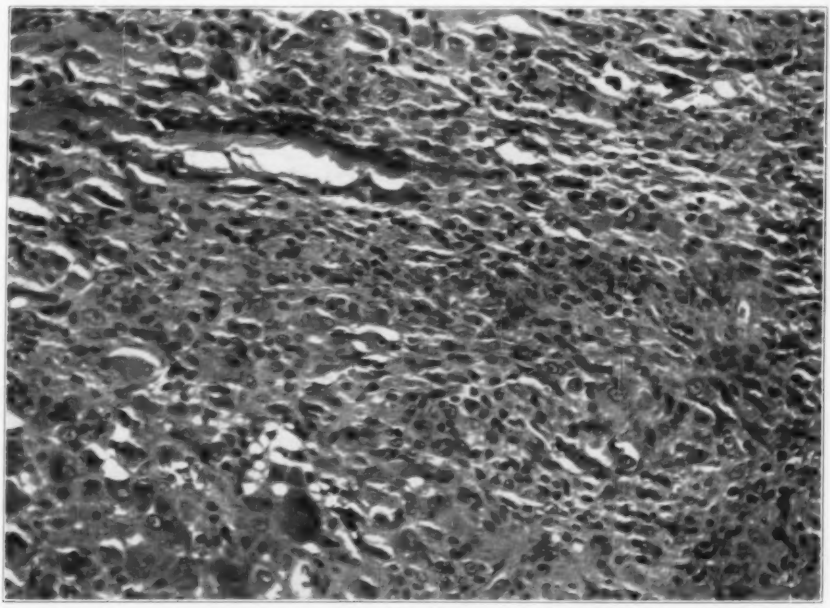

FIG. 6

Photomicrograph (× 200) of a section taken from the tendon sheath, showing the fully developed cellular lesion.

FIG. 7

Photomicrograph (× 107) showing hyalinization of stroma in a tendon-sheath lesion.

in the tenosynovial tissues into which the lesion extended. Pigment-containing macrophages were commonly found in focal collections scattered irregularly throughout the nodule (Fig. 4). These aggregates possibly represented macrophages originally present in a single villus which had, on fusion of the latter, come to lie deep in the nodule, maintaining their intimate relationship one to another. Single pigment-laden macrophages were also seen, and pigment was commonly found in extracellular positions. Iron stains indicated that this pigment was hemosiderin. Present in variable numbers were lipid-filled macrophages, their contents probably derived from red-cell degeneration (Fig. 6). These were either present in focal collections or they were scattered diffusely through the lesion. When present in small numbers, they were often found at the periphery of the lesion.

The synovial membrane develops from the perichondrial mesenchyme.[4] Its cells are relatively undifferentiated and doubtless are the origin of the cellular components of the nodules. It is not surprising, therefore, to find foreign-body giant cells developing from the cells of the synovial lining, as well as from the centrally placed stroma. Although they are a distinctive feature of the histological picture, they may be present in only small numbers.

In the fully developed cellular stage the lesion was a complex mixture of giant cells, pigment-laden macrophages, foam cells, and occasional synovium-lined clefts, embedded in a stroma of polygonal or rounded cells (Fig. 6), the whole being incompletely encapsulated by a layer of connective tissue. Despite the wide variation in number and distribution of component cells in a lesion, the over-all histological appearance was very distinctive. During the late stage there was a gradual replacement of cellular elements by connective tissue which was subsequently hyalinized (Fig. 7). Nests of any of the cellular components were found, but especially small giant cells and synovium-lined clefts. The late disappearance of the latter is probably to be explained by the relative difficulty with which scar tissue can obliterate a space possessing a definite lining. Degenerative changes, including the formation of cholesterol clefts, occur.

DISCUSSION

In spite of the small size of the lesion in pigmented villonodular synovitis and the lack of dramatic symptoms, it has received a surprising amount of attention. The theories of its pathogenesis encompass virtually all the possibilities. Thus, Geschickter and Copeland suggested that it represents a tumor arising in a sesamoid bone in a tendon. They supported this view by saying that the frequency of sesamoid bones in fingers accounts for the high incidence of the lesions at this site. Young and Hudacek recently published the results of experiments calculated to demonstrate the role of hemorrhage in the production of the lesions both in the synovial membrane of the knee and in tendon sheaths. Examination of the joints into which autogenous blood had been injected at intervals of from one to three times weekly, for periods up to a year, led them to the conclusion that ". . . Repeated hemorrhages into the joint are essential for the development of this lesion, and trauma is often the initiating factor". Similar experiments were carried out on the Achilles tendon. These failed to produce the characteristic appearance of the lesions of pigmented villonodular tenosynovitis. The authors explained, however, that the tendon sheath of the Achilles tendon is only vestigial in nature. Since the lesion they sought to produce involves the tendon sheath, greater success might have been achieved if blood had been injected into the sheath tissues rather than the tendon itself. Trauma alone has also been advanced as the etiological factor. Other authors[2] suggested that the lesion is due to cholesterol imbalance and classified it as a primary essential xanthomatosis. However, blood cholesterol levels are normal in these patients[5], and it is unnecessary to introduce cholesterol imbalance to explain the presence of lipid, since lipid is often seen in areas of old hemorrhage and chronic inflammation. Since no cases have shown proved transition to malignancy, an oncotic origin is dubious. The natural life history of the nodules also speaks against a neoplastic origin. That the lesions are of an inflammatory nature was proposed by Fleissig in 1913, and later supported by Jaffe, Lichtenstein, and Sutro. While the foregoing would indicate that, so far, no universally acceptable explanation for this lesion has been found, inflammation in its broadest interpretation—reaction to injury—would appear to be the most acceptable.

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THE PATHOLOGY, DIAGNOSIS, AND TREATMENT OF EXTRA-ABDOMINAL DESMOID TUMORS*

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Every surgeon who is responsible for the clinical management of fibrous-tissue tumors of the pelvic and shoulder girdles and of the extremities is faced at times with a problem of differential diagnosis that is much more difficult than is generally recognized. It is the intent of this report to consider this problem in general and to report eight additional cases of extra-abdominal desmoid tumors, as these lesions are frequently mistaken for fibrosarcomata and are consequently grossly overtreated. In order to avoid errors in diagnosis and treatment, the surgeon must be well aware of a group of benign fibrous-tissue lesions which have been classified by Stout under the heading of fibromatoses. This group includes fibromata, keloids, desmoids, penile fibromatosis (Peyronie's disease), plantar and palmar fibromatosis (Dupuytren's contracture), fibromatosis colli (congenital torticollis), progressive myositis fibrosa, and irradiation fibromatosis. All of these conditions show a fibroblastic tissue reaction which may or may not be truly neoplastic and which is essentially benign and self-limited in character, but the etiology of these conditions is not necessarily similar.

In this group of benign lesions, three conditions have to be carefully differentiated from fibrosarcoma. Irradiation fibromatosis, as has been shown by Pettit, Chamness, and Ackerman, may undergo malignant alteration into fibrosarcoma and is definitely a premalignant lesion. Patients with such lesions always give a history of irradiation therapy to the involved area and the lesions are not difficult to distinguish from other fibromatoses. Desmoid tumors and plantar fibromatosis, on the other hand, although sometimes mistakenly diagnosed as fibrosarcoma, do not develop into malignant tumors. Pedersen and Day have recently shown evidence that plantar and palmar fascial lesions represent a reactive fibroplasia following degenerative disease of the fascia and have emphasized the problem of differentiating these lesions from fibrosarcoma.

It is of prime importance in establishing an accurate diagnosis of these soft-tissue lesions to have adequate representative tissue for microscopic study. Only if such lesions are small and so located that wide excision can be done without either functional or serious cosmetic impairment should an excision biopsy be performed. In all other cases an incisional biopsy should be performed and an accurate diagnosis should be made before definitive treatment is advised. By adhering strictly to this principle, the surgeon will avoid mistakes.

Desmoid tumors are non-metastasizing, locally invasive fibrous-tissue tumors. This lesion was first described as occurring in the abdominal wall by Macfarlane of Glasgow in 1832. During the next 100 years his description was followed by reports of hundreds of cases. Nichols was the first, in 1923, to report lesions in locations other than the abdominal wall with the identical gross and microscopic pictures and a similar course. He reported twenty-five tumors of the abdominal wall together with six clinically and pathologically similar tumors; these extra-abdominal lesions were located in the thigh, glutaeus maximus, popliteal space, adductor longus, pectoralis major, and serratus anterior. Since then numerous other case reports of extra-abdominal lesions have appeared. It would appear that musculo-aponeurotic structures throughout the body are capable of giving rise to such

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Los Angeles, California, February 3, 1955.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. Clinical photograph made two and a half years after removal, with the overlying skin, of a desmoid tumor from the deltoid muscle and closure by a split-skin graft. Recurrent nodules of tumor may be readily seen.

Fig. 1-B: Gross specimen obtained at re-excision of the entire tumor-bearing area shown in Fig. 1-A. Note the lack of encapsulation and infiltration into the deltoid.

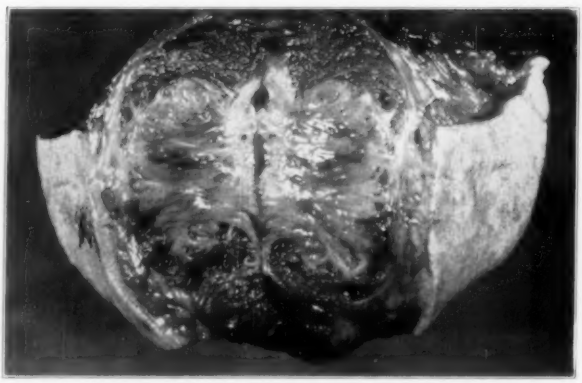

FIG. 2

Fig. 2: Gross specimen of a large extra-abdominal desmoid from the shoulder, demonstrating the engulfing of muscle fibers by encircling fibrous strands. (Reproduced by permission from Principles in Management of Soft Tissue Sarcomas. A Clinical and Pathologic Review of One Hundred Cases, by Zelig Lieberman and L. V. Ackerman. *Surgery*, **35**: 352, 1954.)

tumors. A comprehensive report by Musgrove and McDonald describing thirty-four extra-abdominal tumors indicates that for every such case there are approximately two cases occurring in the abdominal wall. The etiology remains obscure, although trauma and endocrine disturbances are suspected as playing a role. The relatively frequent occurrence of this lesion in the abdominal wall of multiparous women in whom the abdomen has been subjected to the physiological trauma of pregnancy, and its occurrence in the site of an abdominal surgical scar have been cited by Masson as favoring the traumatic theory of etiology. One of the cases herein reported occurred at the site of a surgical scar made for removal of a lipoma in the same area. The endocrine influence is demonstrated by a case, reported by Pack and Ehrlich, of an inoperable abdominal desmoid which regressed markedly following irradiation castration; Lipschütz and Grismali showed experimentally that estrogenic substances are fibromatogenic and that synthetic progesterone is anti-fibromatogenic in guinea pigs.

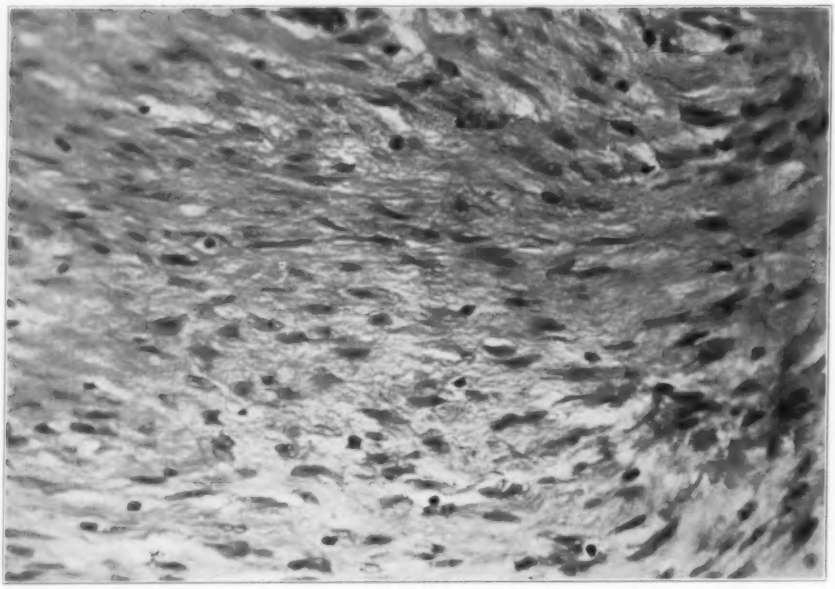

FIG. 3

Photomicrograph (× 300) showing a typical field from a desmoid tumor with prominent intercellular collagenous fibers, uniform fibrocytic cells, and absence of mitoses.

FIG. 4

Photomicrograph (× 150) showing a field from the margin of a desmoid tumor, with absence of capsular structures, separation of muscle bundles, and fragmentation of muscle fibers. (Reproduced by permission from Principles in Management of Soft Tissue Sarcomas. A Clinical and Pathologic Review of One Hundred Cases, by Zelig Lieberman and L. V. Ackerman. *Surgery*, **35**: 352, 1954.)

TABLE I

SUMMARY OF EIGHT CASES OF DESMOID TUMOR

Case No.	Age, Sex	Race	Duration (*Months*)	Size and Location of Lesion	Operation	Follow-up and Remarks
1	29 F	Negro	8	7 by 7 by 5 centimeters, right deltoid	November 1950. Radical excision and split graft.	June, 1953, recurrence; re-excision and split graft. At six months, no further recurrence. Good arm function.
2	23 F	Negro	2	8 by 8 by 6 centimeters, left popliteal space	February 1952. Radical excision sacrificing large vessels.	Feb. 20, 1952, thigh amputation for gangrene. No recurrence twenty months later.
3	33 F	White	12	4 by 5 by 3 centimeters, trapezius	May 1950. Local excision.	January 1954, no recurrence.
4	2 F	White	1	3 by 4 by 3 centimeters, tibialis anterior	February 1953. Local excision.	January 1954, no recurrence.
5	25 M	White	24	6 by 6 by 6 centimeters, right scapula	August 1949. Shoulder-girdle amputation.	September 1953, no recurrence.
6	2 M	White	2	4 by 3 by 3 centimeters, upper antecubital fossa	June 1950. Incomplete resection to avoid vessels.	September 1953, no recurrence. No limitation of function of arm.
7	61 F	White	8	8 by 6 by 4 centimeters, left trapezius	July 1948. Local excision.	September 1953, no recurrence.
8	39 F	White	12	4 by 4 by 5 centimeters, left trapezius and suprascapular muscles	October 1953. Local excision.	March 1954, no recurrence. Lipoma removed from same region January 1953.

Clinically, the patient presents himself with a mass which is associated with some discomfort but which usually is not very painful. The history reveals that the tumor has very slowly enlarged since it was first noted by the patient. The mass is firm and poorly delineated and may be slightly tender. The skin moves freely over the mass, but the mass is usually firmly attached to the underlying musculo-skeletal structure. If the tumor is located close to a mobile joint, limitation of motion may be present.

In this series there were six females and two males; and their ages ranged from two to sixty-one years. The location of these lesions is listed in Table I.

Grossly, these tumors always arise in close association with musculo-aponeurotic structures. By the time the tumor is clinically evident, it is not possible to tell whether it arose from within the muscle, from the perimuscular fascia, or from the muscular aponeurosis. The extra-abdominal tumors in this series varied in size from four by three by three centimeters to eight by eight by six centimeters and were slightly ovoid, with the longest diameter in the direction of the muscle fibers of the muscles in closest association with the tumor. They were yellowish-white in color, very firm in consistency, and somewhat lobulated on cut section. Their primary distinguishing gross characteristic is an irregular margin, lack of encapsulation, and infiltration into surrounding muscle (Figs. 1-A, 1-B, and 2). The overlying skin has not been attached in any patient who had not had previous surgery, but the tumor may be so closely associated with underlying bone structure that it appears to be attached. There has been no direct invasion of bone or periosteum.

Microscopically, the tumor consists of collagenous fibrous tissue with prominent inter-

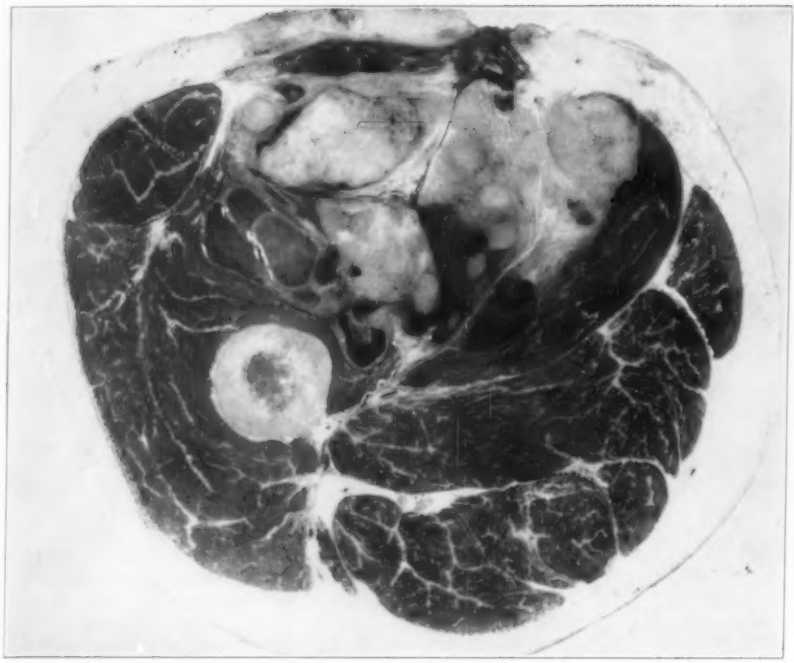

FIG. 5-A

Cross-section of amputation specimen showing a fibrosarcoma in the lower portion of the thigh. Note the irregular but distinct border, with partial encapsulation. (Reproduced by permission from Principles in Management of Soft Tissue Sarcomas. A Clinical and Pathologic Review of One Hundred Cases, by Zelig Lieberman and L. V. Ackerman. *Surgery*, **35**: 354, 1954.)

cellular substance and only moderate cellularity (Fig. 3). The cells appear to be typical adult fibrocytes which are uniform in size and shape throughout the tumor. Mitotic figures may be seen rarely but pathological mitoses are never seen. There has been no degeneration or necrosis in the tumors of this series, although these processes are seen in the center of the larger abdominal tumors. At the advancing edge of the tumor, it is characteristic to see muscle fibers caught in the tumor tissue and in varying stages of degeneration, with pyknotic nuclei and loss of cross-striation (Fig. 4). There is no evidence of true encapsulation. There is no hemorrhage, and inflammatory reaction is limited to peripheral lymphocytic infiltration, occurring only in some cases. There is slight internal lobulation of the fibrous-tissue masses making up the tumor.

Microscopically desmoid tumors are similar to fibromatosis of the palmar and plantar fascia (Dupuytren's contracture), but the discrete nodule formation and lack of muscle infiltration in the latter condition suggest a different pathological entity.

The lesion with which desmoid tumors are most likely to be confused is low-grade fibrosarcoma. It must be admitted that occasionally the distinction may be difficult, but it is believed that the majority of tumors can be clearly distinguished if certain pathological features of fibrosarcoma are kept in mind. The primary characteristics of fibrosarcoma which serve for comparison with the desmoid tumor are: (1) strong tendency toward encapsulation, (2) greater cellularity, (3) frequent mitotic figures, and (4) atypical mitoses (Figs. 5-A and 5-B).

According to Pack and Ariel the treatment of choice in fibrosarcoma of the extremities is amputation unless wide surgical excision with a four to six centimeter margin of normal tissue is feasible. Such radical treatment is not necessary in the treatment of extra-ab-

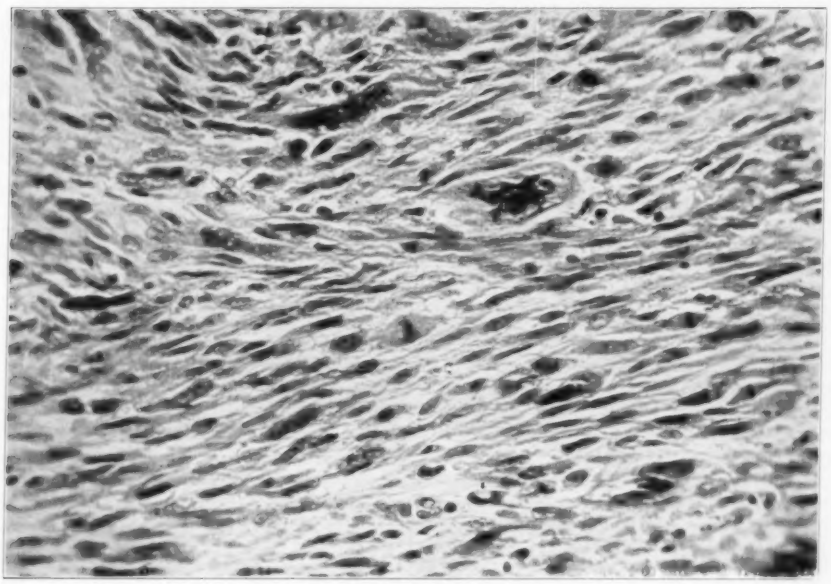

FIG. 5-B

Photomicrograph (× 300) showing a field from the same tumor shown in Fig. 5-A, with marked cellularity, several mitoses, and a large, atypical mitotic figure.

dominal desmoid tumors; care must therefore be taken to distinguish between these lesions before any surgical treatment is planned.

As the desmoid tumor is a non-metastasizing but locally invasive lesion, it is reasonable to expect that radical local surgical excision would be the treatment of choice. The experience of others has indicated a high percentage of recurrences following such surgery; however, these recurrences have not been associated with an increase in the aggressiveness of the lesion and have been handled satisfactorily by additional surgical excision. Since the tumor sometimes occurs in close association with major peripheral vascular and neural structures, as in Cases 2 and 6, it is felt that an incomplete local excision is to be preferred to sacrificing an extremity. In this series, two major amputations were performed. In Case 5 an erroneous diagnosis of fibrosarcoma was made after biopsy, leading to radical amputation as elective treatment. In Case 2 a radical local excision was performed which necessitated sacrificing the major vessels; this resulted in gangrene, so that amputation followed. In Case 6 an incomplete excision was done in order to preserve the vascular structures of the antecubital fossa; a four-year follow-up shows no evidence of recurrence.

Roentgen therapy was not used in any cases of this series but has been used in inoperable abdominal desmoids with varying results. The use of progesterone in the treatment of these lesions has not been reported to date.

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DISCUSSION

Dr. Weldon K. Bullock, Los Angeles, California: The excellent report of this unusual fibroblastic lesion is impressive in that it describes a lesion that is to be reckoned with, particularly when inaccessible to surgical procedures. I agree with everything that Dr. Ramsey has said about this lesion. I would like to present a case in a colored woman, twenty-one years old, in whom some months after delivery at term, a mass developed in the posterior triangle of the neck. This mass grew slowly and after about six months she entered Los Angeles County Hospital for diagnostic studies. She was sent to the eye-nose-and-throat department, where it was noted that she had a lesion in the nasal tract which was believed to be malignant. Under general anaesthesia, the nasopharyngeal lesion was explored and found to be Thornwaldt's bursitis, and the neck mass was therefore explored. This was only partly removed and frozen section revealed it to be an extra-abdominal desmoid. During the next year this patient was operated on four times for residual tumor, but at no time was it possible to remove the tumor from around the carotid sheath and the internal jugular vein. The original tumor had been in the trapezius, but later it involved the sternocleidomastoid. At the last operation, one year and a few weeks after the first operation, Dr. Louisa Keasbey, a pathologist in Los Angeles, suggested that the patient be placed on testosterone. This was done, 100 milligrams being given three times a week, and the patient was observed from time to time. It was noted at the time of the fifth recurrence, that even with testosterone therapy the lesion had not subsided. Re-exploration was done and again the tumor was only partially removed. Testosterone therapy has been continued for over a year without recurrence.

Dr. Ramsey (closing): In regard to the hormonal therapy which has been suggested, the experimental work of Lipschütz and Grismali showed that fibroblastic lesions similar to desmoid tumors have been produced in guinea pigs by the administration of estrogenic substances and that these same lesions can be inhibited by the administration, simultaneously, of progesterone. Thus although we do not know what causes these lesions, there is good evidence that some endocrine imbalance is involved.

FIBROSARCOMA ARISING IN AN APPARENTLY BENIGN FIBROUS LESION OF BONE *

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Sarcoma of bone spontaneously arising from or associated with a pre-existing, seemingly benign fibrous lesion of bone is a rare occurrence. A review of the literature yielded only five histologically documented cases. Two instances of fibrosarcoma arising in polyostotic fibrous dysplasia were reported by Coley and Stewart. The third case, an osteogenic sarcoma in a limb affected with polyostotic fibrous dysplasia, was reported by Sutro. The fourth case of a sarcoma developing in a patient with polyostotic fibrous dysplasia was reported by Dustin and Ley, and recently Perkinson and Higinbotham have reported a fifth. Other instances of sarcoma arising in seemingly benign fibrous lesions of bone have been described by others [1-7]. However, in these reports, the malignant transformations were complicated by and causally attributed to irradiation or lacked adequate histological proof.

We wish to report a case which in several aspects was not similar to any of these and which presented a particularly interesting and controversial problem as to the diagnosis and proper therapy. Because of the unusual features and rarity, this case report seems warranted.

CASE HISTORY

W. N. M., white male, aged thirty-two, was admitted to Fayetteville Veterans Hospital on January 9, 1948, because of a persistently tender area on the anterior aspect of the right leg. On December 17, 1947, the patient had struck his right shin on a metal object; he denied any symptoms referable to the right leg prior to that date. The family history, past history, and review of systems were non-contributory.

Physical examination was essentially negative except for a slight fusiform swelling of the right leg anteriorly about four inches below the knee. The area was moderately tender and warm. Laboratory findings were normal. Roentgenograms revealed an osteolytic lesion of the upper right tibia; otherwise, both lower extremities and the pelvis were normal roentgenographically.

Surgical exploration on January 9, 1948, disclosed that the lesion consisted of dense avascular fibrous tissue. The area was curetted and was packed with bone chips obtained from the iliac crest. The histological report was "fibrous dysplasia". The patient made an uneventful recovery.

On August 11, 1952, the patient was re-admitted to Fayetteville Veterans Hospital because of pain in the right leg of six months' duration. The pain was aggravated by walking, while heat applied locally and rest afforded considerable relief. In the two months prior to admission, the pain had increased in severity. The patient stated that he had received an accidental kick to the operative site in early 1951.

The only pertinent findings on the second admission were swelling and tenderness over the medial aspect of the upper third of the right tibia. Roentgenograms showed extension of the osteolytic lesion. On August 15, 1952, the area was again curetted and packed with bone chips. The tissue removed was described as being gray and rubbery and was again diagnosed microscopically as "fibrous dysplasia". During the year following the second hospital admission, the patient continued to suffer from intermittent pain in the right leg both when walking and when at rest.

The patient was admitted to the Hospital for the third time on July 23, 1953, because of a sudden increase in the pain of ten days' duration. Diffuse swelling of the upper third of the right leg was present. This was associated with tenderness, particularly below the medial tibial plateau. Roentgenograms showed additional bone destruction. Biopsies of two areas, one below the medial plateau and the other along the posterior aspect laterally, were performed on July 27, 1953. For the third time a pathological diagnosis of "fibrous dysplasia" was made.

* Reviewed in the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions published by the authors are a result of their own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

FIG. 1

FIG. 2-A

FIG. 2-B

Fig. 1: January 9, 1948. This lateral roentgenogram clearly demonstrated the large elliptical rarefaction in the right tibia.

Figs. 2-A and 2-B: February 10, 1948. Anteroposterior and lateral roentgenograms showed the inferior tongue-shaped projection of the destructive area and also several tiny bone chips which had been added at the time of curettage.

FIG. 3

FIG. 4

FIG. 5

Fig. 3: August 6, 1952. Lateral roentgenogram revealed extension of the osteolytic process. The region of the trabecular smudging in the proximal portion of the shaft of the tibia had become radiolucent.

Fig. 4: September 15, 1952. Bone chips with which the curetted cavity was filled in August are seen in this lateral roentgenogram.

Fig. 5: December 19, 1952. Lateral roentgenogram showing resorption of the bone chips.

FIG. 6

February 19, 1953. Lateral roentgenogram disclosed marked resorption of the bone chips.

In October 1953, the microscopic slides were reviewed by another pathologist who classified the lesion as a "benign central fibroma of bone". The histological features consisted of fibrous connective tissue with interspersed bony trabeculae. In many places, the bony trabeculae were completely absent, and the tissue thus presented a fibromatous appearance. There was no histological evidence of malignancy (Figs. 9-A and 9-B).

About the same time, one of us (S. R. B.) reviewed all of the roentgenograms and reported the following conclusion: "Osteolytic lesion of the proximal right tibia with the clinical features of a very slowly progressive malignant lesion, such as fibrosarcoma of bone, Grade 1, but lacking histological proof of malignancy. Recommendation — amputation."

Roentgenographic Review

This conclusion and recommendation were based upon a detailed review of the roentgenograms. The first roentgenogram (Fig. 1), dated January 9, 1948, showed an almost elliptical rarefaction, seven centimeters by 2.8 centimeters, which began eight centimeters from the proximal portion of the tibial articulating surface. This was accompanied by a slight expansion (two to four millimeters) of the diameter of the shaft. The interior was not completely radiolucent but, instead, had a smudgy appearance. The anterior, posterior, and lateral limits of the lesion were sharp, and there was erosion of the inner aspects of the cortex. The medial margin was hazy both on its endosteal as well as on the periosteal aspect. Its superior limit was less well defined and merged proximally with a region, four centimeters in extent, in which the trabecular pattern had become smudged. There was no evidence of any peripheral denser rim or sclerotic reaction. The roentgenograms made February 10, 1948, (Figs. 2-A and 2-B) showed the same findings and the several tiny bone chips which had been added after curettage. The inferior margin had a more clearly defined tongue-shaped configuration. The roentgenograms made March 3, 1948, and May 21, 1948, presented no appreciable changes.

In the roentgenogram dated August 6, 1952, (Fig. 3) the region of trabecular smudging in the proximal portion of the shaft of the tibia became radiolucent with evident bone destruction extending to within three centimeters of the articulating tibial surface; the osteolytic lesion now measured thirteen centimeters in length. The medial cortical margin was evidently bearing the brunt of the destructive process, since it showed more dissolution on both endosteal and periosteal aspects. The roentgenograms made September 15, 1952, (Fig. 4) showed the addition of bone chips throughout the extent of the cavity left after the curettage of the lesion. The roentgenograms of December 19, 1952, and February 19, 1953, (Figs. 5 and 6) revealed marked resorption of the bone chips with further proximal extension of the lytic process. The roentgenograms of July 23, 1953, (Fig. 7) and of October 30, 1953, (Figs. 8-A and 8-B) showed that the lesion had definitely broken through the cortex at the medial aspect, just below the condylar region. When compared with the roentgenogram made February 10, 1948, the latest roentgenogram showed that the expansion of the tibial shaft amounted to seven millimeters in the anterior-posterior direction and thirteen millimeters in the lateral direction. The extension

FIG. 7

FIG. 8-A

FIG. 8-B

Fig. 7: July 23, 1953. Anteroposterior roentgenogram.

Figs. 8-A and 8-B: October 30, 1953. Lateral and oblique roentgenograms showed a marked progression of the destructive process and that the lesion had broken through the cortex at the medial aspect, just below the condylar region.

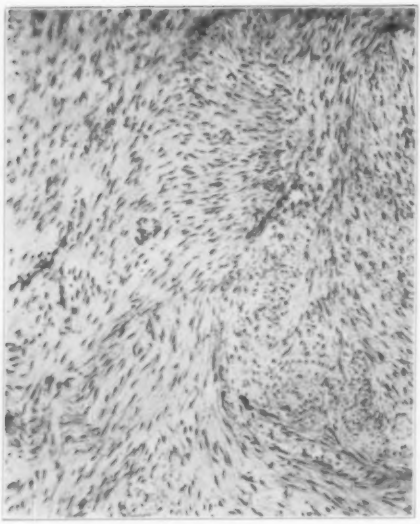

FIG. 9-A

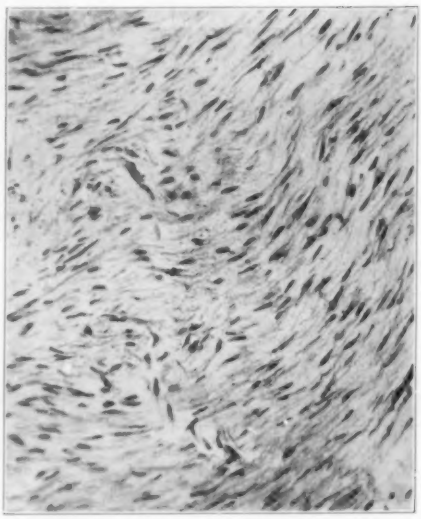

FIG. 9-B

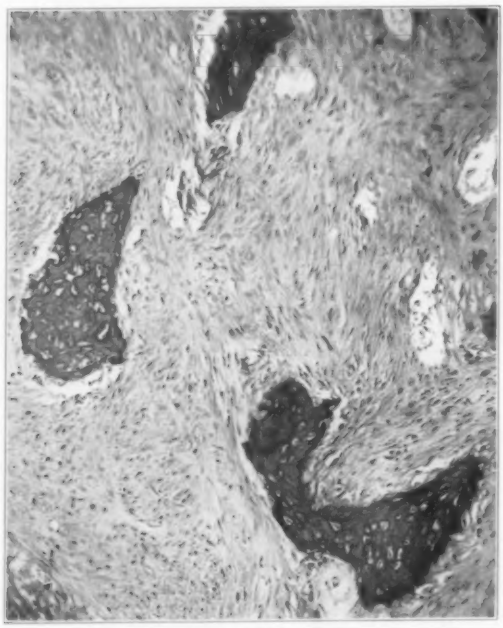

FIG. 9-C

Figs. 9-A (× 83), 9-B (× 166), and 9-C (× 100): Histological sections (hematoxylin and eosin stains) prior to amputation revealed a benign fibrous lesion. The pattern in some areas was that of a fibroma (Figs. 9-A and 9-B), while in others the appearance conformed to fibrous dysplasia (Fig. 9-C).

of the lytic process in the distal direction during the five and one-half year interval amounted to less than one centimeter.

On October 28, 1953, at the patient's own request, he was transferred to the Mt. Alto Veterans Hospital in Washington, D. C. Examination at this time disclosed a tender symmetrical enlargement of the upper third of the right leg exhibiting an elevation in local temperature. The patient was presented for examination to the Tumor Board, and in accordance with its recommendation a mid-thigh amputation was performed on November 3, 1953. Postoperatively, there was some difficulty with phantom-limb pain. This, however, responded to therapy. A rehabilitation program was carried out, and the patient was fitted with a suction-socket prosthesis. When last heard from in August 1954, he was well and working daily.

Pathological Findings of the Amputated Specimen

On gross examination, several nodules of tumor tissue, up to two centimeters in diameter, were found to have extruded through the posteromedial cortex of the tibia and to have extended into the overlying muscle.

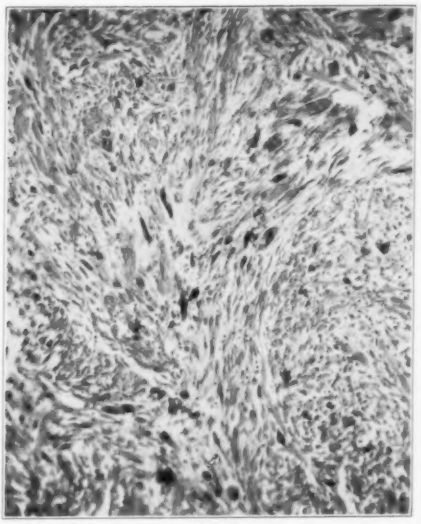

FIG. 10-A

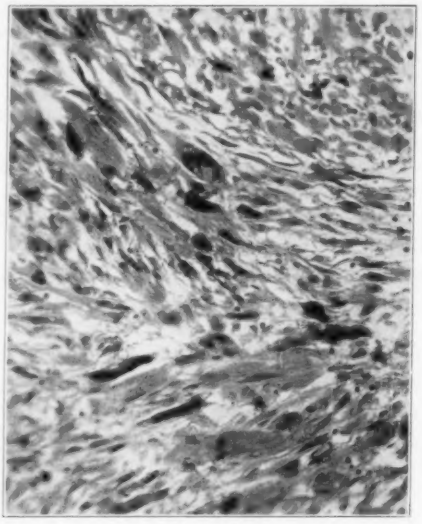

FIG. 10-B

Figs. 10-A (× 83) and 10-B (× 166): Histological specimens (hematoxylin and eosin stains) from the amputated limb, showing the typical pathological features of fibrosarcoma.

These nodules appeared to be encapsulated. The longitudinally bisected tibia revealed the entire marrow cavity of its proximal fifteen centimeters to have been obliterated and replaced by firm, whitish-gray, fibrous tissue. The proximal three centimeters had the normal gritty feel of bone but was somewhat light in color and seemed to be at least partially infiltrated by tumor. At the distal margin, the grayish-white tumor disappeared gradually.

Microscopically, the tissue exhibited frank fibrosarcoma in many areas, as evidenced by marked cellularity with plump atypical fibroblasts, mitoses, and tumor giant cells (Figs. 10-A and 10-B). These sarcomatous features were present at the area of perforation of the cortex, where the malignant tumor was found to have extended into the surrounding striated muscles. However, in the older portions of the tumor, there were still many areas where poorly cellular collagenous tissue prevailed, similar to the benign-appearing fibrous tissue found in the previous biopsies.

DISCUSSION

The pathological classification of benign fibrous lesions of bone of unknown etiology is a controversial subject. The exact label which will be attached to a particular slide will vary with the times and according to the center in which the diagnosis is made. Except for the attempt of some groups to separate non-osteogenic fibroma [5], central fibroma, and ossifying fibroma as distinct entities, the current trend is to classify all of these benign fibrous lesions under the generic term of fibrous dysplasia. Ossifying fibroma is now regarded by many pathologists as a manifestation of fibrous dysplasia. Both non-osteogenic fibroma and central fibroma present the same basic histological pattern as fibrous dysplasia. They are all composed of fibrous tissue with variations in the degree of cellularity, in the presence or absence of osseous metaplasia, giant cells, lipoid cells, hyaline cartilage, and myxomatous elements. A view proposed by Hatcher suggests a correlation between the metaphyseal fibrous defects, thought to be due to a vascular disturbance, and non-osteogenic fibroma. Schlumberger regards non-osteogenic fibroma as a variant of fibrous dysplasia. It remains to be seen whether central fibroma will be retained as a separate entity.

Prior to the amputation, five pathologists studied all or part of the microscopic sections. Four diagnosed the process as fibrous dysplasia; the fifth classified it as a central fibroma. Although there was disagreement as to the diagnosis, the really significant

point in this case is that all of the pathologists agreed that the process was benign. This difficulty or impossibility of diagnosing already present or imminent fibrosarcoma raises two important questions:

First: Was the original lesion a low-grade medullary fibrosarcoma from the start? Although it cannot be categorically denied, this possibility seems unlikely. One is justified in assuming that the original lesion existed in its benign phase for a considerable period of time prior to clinical detection, since a fully established expansile rarefaction, seven centimeters in length, was found only three weeks after the first complaint.

Second: Did the malignant transformation set in at the time of the first appearance of symptoms in December 1947? In other words, did all of the pre-amputation biopsy specimens represent a low-grade fibrosarcoma without recognizable histological evidence of malignancy, superimposed upon the previously benign fibrous process? Clinically, the answer seems to be in the affirmative. Thus, secondary fibrosarcoma superimposed upon a benign fibrous lesion would be similar to a secondary chondrosarcoma arising in an osteochondroma. In the latter instance, pathologists readily concede that even multiple biopsies may not reveal any recognizable sarcomatous transformations, and they freely advise relying upon the roentgenographic and clinical findings. A similar quandary was encountered by Willis in a case of fibrosarcoma which had originally been diagnosed as osteitis fibrosa but which later demonstrated the histological features of a mass of fibrous tissue, which infiltrated the adjacent muscles and fatty tissue and was densely fibrous and poorly cellular. Its "nuclear features and infiltrative properties led to the conclusion that it was a slowly growing, lowly malignant fibrosarcoma. . . ."

The therapeutic approach presented another difficult problem. The patient had already been advised by orthopaedic surgeons elsewhere that he needed x-ray treatments. In fact, the case was referred to us with the express purpose of transferring the patient for irradiation. The reviewing roentgenologist (S. R. B.) included the following reasoning for advising against roentgen therapy: "X-ray therapy would possibly ameliorate the symptoms temporarily. However, it would only confuse an already puzzling and unusual case. In this connection it might be worthwhile to refer to the reported two cases of 'Bone Sarcoma in Polyostotic Fibrous Dysplasia', by Coley and Stewart and note that, although improvement followed irradiation, it did not prevent the occurrence of a fracture and metastases". Had roentgen therapy been employed in a case in which the clinical course was so progressive, the appearance of fibrosarcoma would have been blamed upon the irradiation, as has been unjustifiably done in some instances.

When surgical extirpation is feasible, we strongly urge that radiation therapy not be employed for osteolytic fibrous lesions of bone, in which the clinical course and the progressive roentgenographic bone destruction do not agree with benign biopsy reports. If sarcoma is already present, irradiation will not effect a cure. Should sarcoma later manifest itself, irradiation might unjustifiably be blamed for it. In a symptomatic fibrous bone lesion which is truly benign and remains so, complete surgical eradication affords the best chance of cure.

NOTE: The authors wish to express their thanks to the personnel of the Medical Illustration Laboratory of the Mt. Alto Veterans Administration Hospital for the preparation of the photographs used herein.

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METABOLIC STUDIES OF CHILDREN WITH IDIOPATHIC SCOLIOSIS *

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Idiopathic scoliosis is a disease most prevalent during the period of rapid prepuberal growth and mineralization of bone. It is refractory to treatment but is arrested spontaneously when growth is completed, although the deformities present at that time are irreversible. The skeletal area involved in this disturbance is relatively large in terms of the total skeleton. It appeared, therefore, that, if the disease is metabolic in origin, changes in the metabolism of calcium and of nitrogen might indicate whether the disturbance is primarily one of calcification or of the metabolism of the protein matrix.

Children with idiopathic scoliosis of varying severity were selected for study. They were housed in a special ward, under care of nurses specially trained for metabolic studies. All children were up and dressed, and had as nearly normal activity as could be provided. They attended the Children's Hospital school, and were taken for walks or outdoor exercise whenever weather permitted. For the metabolic studies, all children were on dietary regimens which provided ample calories and which, for most nutrients, equaled or exceeded the National Research Council dietary allowances for their respective ages. Because utilization of protein, calcium, and phosphorus was the prime object of study, graded amounts of these nutrients were given. The caloric allowance was always sufficiently ample that protein need not be used for calories. Previous studies in this laboratory [3] have shown that calcium retention in well children during the period of rapid growth depends in large degree on the previous level of nutrition of the child; therefore the subjects of this study, with few exceptions, were given ample milk intakes, consisting of a quart or more of milk daily. The milk used contained 400 international units of vitamin D to the quart. A few children were given an additional amount of 500 international units of vitamin D daily. Other vitamins were supplied adequately by the diets. The children received the experimental diet for at least three days before, as well as during, the period of collection of excreta. Diets as well as excretions were analyzed for nitrogen, calcium, and phosphorus. Complete partition of urinary nitrogen was carried out for each subject. Standard methods of analysis were used throughout[2,4,6,8].

The dietary histories revealed a surprising constancy of dietary habits among these children, regardless of either the intelligence or the financial status of their families. The children disliked all foods high in protein and greatly preferred foods high in carbohydrates, such as potatoes and bread. Their nutritional status was generally poor, as the intake of milk, meat, fish, and eggs had been low. The utilization of minerals and nitrogen was studied with at least two levels of intake for each child.

Calcium Retention

The retention of calcium per kilogram of body weight is shown in relation to the per-kilogram intake in Chart I. The scatter of values is wide, but a definite trend of increasing retention with increased intake may be noted. Children of this age group who are in good nutrition and who are receiving moderate amounts of vitamin D will retain increasing amounts of calcium as the calcium intake increases, and will retain ten milligrams or more of calcium per kilogram daily, with an intake of twenty-five to fifty milligrams per kilogram daily.

* The expenses of this investigation were in part defrayed by a grant from the Central Scientific Fund of the College of Medicine, State University of Iowa.

Chart I: Retention of calcium by scoliotic children in relation to the calcium intake.

Chart II: Retention of phosphorus by scoliotic children in relation to the phosphorus intake.

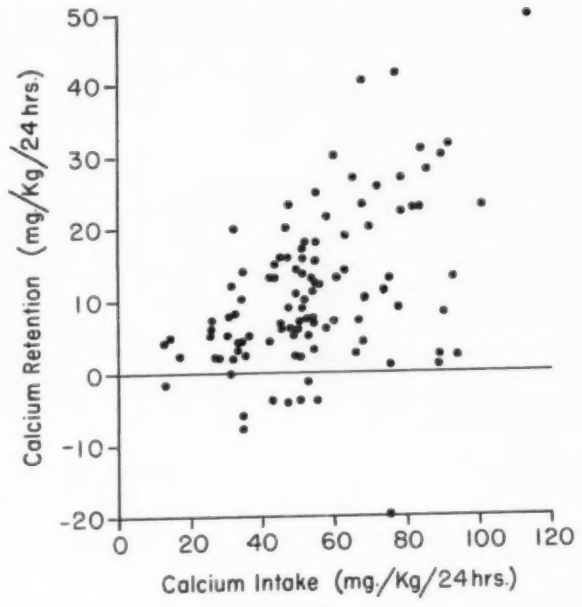

CHART I

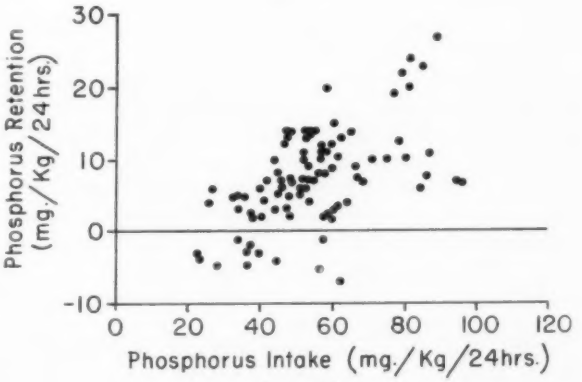

CHART II

As would be expected from the history of habitually poor nutritional status, several of the children were unable at first to retain amounts of calcium considered adequate. With increased milk intake, and continued good diets, these children all were able to achieve good calcium retention. Very high calcium retentions were often observed when the children were given diets high in both protein and calcium. For example, P. W. (No. 45-1329), a poorly nourished girl of thirteen, was able to retain only six milligrams per kilogram of calcium from a diet containing a quart of milk; her daily calcium intake was 1.57 grams, or fifty milligrams per kilogram. When she was given a high-protein, high-calcium diet, the day's calcium intake was increased to 2.3 grams, or seventy-four milligrams per kilogram, and the retention to eleven milligrams per kilogram, a normal retention for her age. This girl was kept in the Hospital on a high-calcium, high-protein regimen for three months; with the same calcium intake, seventy-four milligrams per kilogram, she was then retaining thirty milligrams per kilogram, a very high retention for this age, and indicative of ability to deposit calcium in bone rapidly. Another poorly nourished girl of twelve years, I. M. (No. 50-10178), lost two milligrams of calcium per kilogram on a diet providing seventy-three milligrams per kilogram. After two weeks on the high-calcium, high-protein regimen, with an intake of eighty-six milligrams of calcium per kilogram, her retention increased to sixteen milligrams daily; after a month of the new dietary regimen, her retention was twenty-eight milligrams per kilogram. These two girls both suffered from scoliosis with rapidly increasing deformity at the time the studies were instituted.

Consistent severe losses of calcium from the body, such as are observed in patients with neoplastic bone destruction, osteomalacia, or acute osteoporosis, were never observed. The increasing retention observed after good nutrition had been maintained for some time; and the high calcium-retention values often found in these children with scoliosis indicated

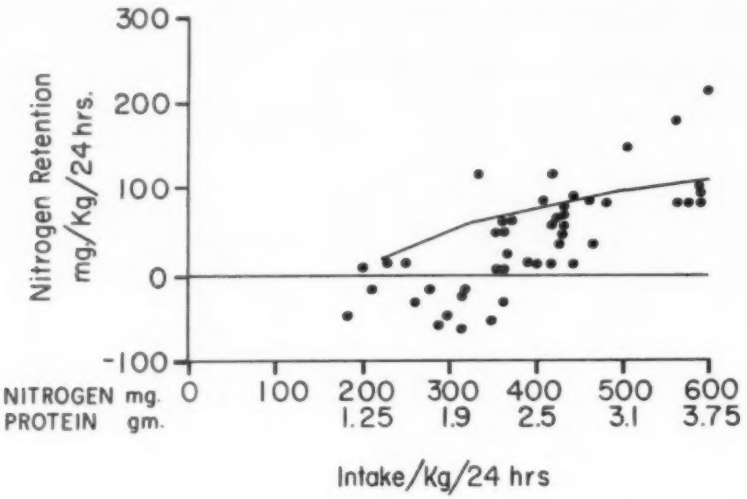

CHART III

Retention of nitrogen by scoliotic children in relation to nitrogen intake. The curved line shows the mean retention of normal children of the same age range.

that any defects of calcium metabolism were the result of poor nutritional status rather than disease.

Phosphorus Retention

Phosphate is essential for the formation of the lattice structure of bone mineral, and is also a necessary constituent of enzymes and other organic substances of the soft tissues. It is usually considered that the soft tissues have priority if the phosphorus retention is inadequate for both soft tissue and bone. The amount needed by the soft tissue will vary with the rate of growth of the various nitrogenous tissues and is not known with exactness. In new calcification of bone, the calcium-phosphorus ratio is about 2.2 to 1. A calcium-phosphorus retention ratio of between 1.5 to 1 and 1 to 1 is usually considered to allow sufficient phosphorus to cover both the nitrogen and the calcium needs of children[7]. A total retention of approximately ten milligrams of phosphorus per kilogram or more is considered desirable in children.

The values for phosphorus retention in milligrams per kilogram compared to the intake per kilogram are shown in Chart II. The data are similar to those for calcium. A few of the children lost phosphorus on moderate or ample intakes of this nutrient. As was the case in the calcium findings, continued good dietary regimens resulted in good retention of phosphorus. Some of the children retained more phosphorus than calcium when they were first studied; soft-tissue growth was better than bone mineralization. For example, P. W. (No. 45-1329) retained eight, ten, and fourteen milligrams of phosphorus per kilogram, with intakes of fifty-six, seventy-one, and sixty-five milligrams per kilogram. The corresponding calcium retentions were six, eleven, and thirty milligrams per kilogram. During the first study, more phosphorus must have been used for soft tissue than for bone; during the last study, it appeared that all the phosphorus retained must be deposited in bone. I. M. (50-10178) lost five milligrams per kilogram of phosphorus from the body, as well as two milligrams of calcium per kilogram during the first study. With the increased intakes of mineral and protein she was able to retain eleven and nineteen milligrams per kilogram, with an intake of seventy-seven milligrams of phosphorus per kilogram; the corresponding calcium-retention values were sixteen and twenty-eight milligrams per kilogram daily.

The mean phosphorus retention for the entire group was nine milligrams per kilogram; the mean calcium-phosphorus retention ratio was 1.4 to 1. This retention ratio is considered satisfactory, and the increased ability of the children to retain both calcium and phosphorus on better dietary regimens is considered to indicate that the primary disturbance is not of calcification.

Nitrogen Metabolism

Study of nitrogen intake and excretion, as indicative of protein metabolism, revealed significant differences between these children and a normal group of the same age range studied in this laboratory [5]. When the protein intake was moderate, 2.0 grams per kilogram or less (equivalent to less than 320 milligrams of nitrogen per kilogram), the children retained it very poorly. In Chart III, the curved line shows the mean nitrogen retention relative to intake of a large group of normal children of the same age range as the scoliotic children. The dots represent nitrogen retention or loss during periods of study of scoliotic children. When the protein intake was less than two grams per kilogram daily (320 milligrams of nitrogen per kilogram daily), three-fourths of the children were losing nitrogen from the body rather than retaining it, as do normal children. When the daily protein intake was increased to between two and three grams per kilogram, in all but two studies the children retained some nitrogen. Only about half the studies showed retention values within the range commonly observed in well children, as shown by distribution about the mean normal curve. Not until the protein intake exceeded three grams per kilogram did the mean nitrogen retention of the scoliotic group equal that of the normal children. Thus, with high protein intakes, the children retained normal amounts of nitrogen, but with the low-protein diets they preferred so strongly, many of them were unable to maintain the body content of nitrogen, much less to increase it sufficiently to permit normal growth.

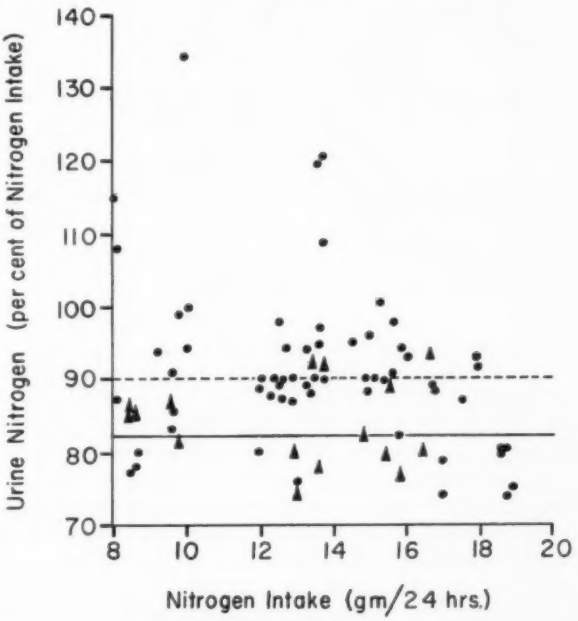

CHART IV

The urinary nitrogen excretion of scoliotic children shown as the percentage of nitrogen intake in relation to the daily nitrogen intake. The solid horizontal line at 82 per cent. represents the mean urinary nitrogen of the group of normal children. The dotted line at 90 per cent. shows the mean excretion of the children with moderate to severe scoliosis. Dots represent data from children with moderate to severe scoliosis; triangles, data from children with mild or arrested scoliosis.

Inspection of the nitrogen data showed that absorption of nitrogen was uniformly excellent. The healthy child usually excretes in the faeces 8 to 12 per cent. of his nitrogen intake; the scoliotic children excreted only 6 to 8 per cent. of ingested nitrogen by way of the bowel. Thus the disturbance was not due to poor absorption.

The scoliotic children, having absorbed nitrogen so well, excreted larger than normal

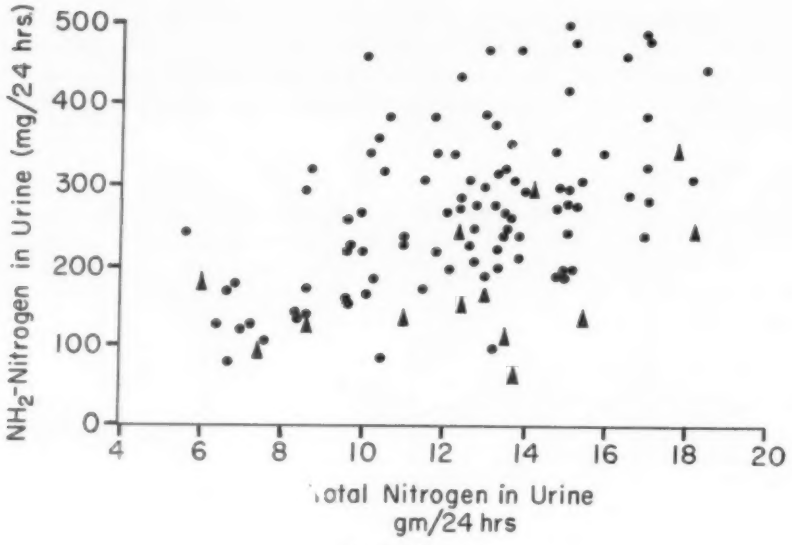

CHART V

The urinary excretion of amino-acid nitrogen by scoliotic children in relation to the nitrogen intake. Dots represent data from children with moderate to severe scoliosis; triangles, data from children with mild or arrested scoliosis.

amounts in the urine. Daily excretion of urinary nitrogen as a percentage of the day's intake is compared with the daily nitrogen intake in Chart IV. The solid line parallel to the abscissa represents the mean percentage of nitrogen intake excreted in the urine by normal children of this age range (82 per cent.). The broken line represents the mean percentage of nitrogen intake excreted in the urine by children with moderate or severe scoliosis * (90 per cent.). Data from individual studies of these children are shown as dots; data from children whose scoliosis was either arrested or was very mild are shown as triangles. It is obvious from the figure that the urinary nitrogen in the latter group was within limits expected of normal children, whereas the urinary nitrogen of scoliotic children was so high that many of those ingesting under sixteen grams of nitrogen daily (100 grams of protein) were unable to retain nitrogen at all. The maximum urinary-nitrogen excretion, reported as a mean value for a five-day period, was 134 per cent. of the nitrogen intake of ten grams daily.

Determination of the various fractions of urinary nitrogen showed that the increase in urinary nitrogen excretion observed in scoliotic children was due largely to increased excretion of urea. Creatine, creatinine, and uric-acid nitrogen levels were within the limits commonly considered as normal. Amino-acid nitrogen appeared to be within normal limits when nitrogen intake was low (Chart V) but increased rapidly with increase in nitrogen intake in many children with severe scoliosis. On the other hand, children whose scoliosis was mild or arrested showed a much lower rate of increase in urinary amino-acid nitrogen with increasing nitrogen intake than that noted for the severely affected children. The fact that the bulk of the increase in urinary nitrogen was due to increased urea excretion is evidence that, in these scoliotic children, body protein is being catabolized at an excessive rate. The relatively normal excretion of nitrogenous constituents other than urea indicates that catabolism of protein, though excessive, seemed to proceed in a relatively

* The terms "mild", "moderate", and "severe" scoliosis refer to the relative rapidity of increase in the degree of spinal curvature. Scoliosis is arrested when no measurable increase in the spinal curvature is noted in six months; arrest usually occurs after cessation of skeletal growth.

TABLE I

URINARY EXCRETION OF TAURINE * BY SEVERELY SCOLIOTIC CHILDREN COMPARED WITH NORMAL SUBJECTS
(Chromatographic Study)

	Age (*Years*)	No. of Determinations	Range (*Milligrams per 24-Hour Period*)	Average (*Milligrams per 24-Hour Period*)	Average (*Micrograms of Taurine per Milligram of Creatinine*)
52 Normal Subjects † (All Ages)					19
16 Scoliotic Children					
P. W.	13	10	96–246	168	272
E. J.	15	9	79–217	148	93
B. H.	14	2	122–160	147	143
M. L.	14	19	72–180	140	138
G. G.	15	6	59–190	130	124
S. H.	15	3	100–168	126	120
J. R.	13	5	85–150	119	107
S. G.	11	13	44–180	115	125
I. M.	12	32	74–148	113	216
J. F.	12	10	69–134	101	131
N. M.	11	5	58–114	89	81
L. J.	15	9	59–117	81	70
J. D.	15	4	40–105	78	88
G. D.	15	3	65–85	73	70
P. L.	12	17	15–110	67	77
D. B.	15	6	25–96	67	67
Total		153	15–246	112	120

* Taurine, or a similar substance containing oxidized sulphur and giving a chromatogram characteristic of taurine.

† These subjects were studied by Williams and his associates [9].

normal manner except for excess wastage of amino acids when protein intake was high.

Chromatographic study of urinary amino acids was undertaken, phenol and lutidine being used as solvents. The number of different amino acids or their derivatives excreted by different scoliotic children varied from six to fifteen. Those most commonly observed were taurine, glutamic acid, glycine, glutamine-citrulline (not separated), alanine, tyrosine, cysteic acid, and methionine sulphoxide. Essential amino acids often excreted in addition to alanine and methionine were threonine, histidine or methyl histidine, leucine, lysine, aspartic acid, and valine.

The substances present in largest amount as shown by this method were taurine, glycine, and methionine sulphoxide. Taurine, while a not uncommon constituent of urine, usually is excreted in small amounts only. Williams and his associates have reported chromatographic studies of normal subjects and mental patients of all ages. Results were measured per milligram of creatinine excretion. By this method of study, seventeen, or 32.7 per cent., of fifty-two subjects excreted no taurine, forty-two, or 80 per cent., excreted less than thirty micrograms per milligram of creatinine, seven, or 13.4 per cent., excreted thirty-one to forty-eight micrograms of taurine per milligram of creatinine, one subject excreted seventy-three and another 130 micrograms of taurine per milligram of creatinine, respectively.

The relative excretion of taurine, measured chromatographically, of sixteen children with moderate to severe scoliosis is shown in Table I. The results are listed both as milligrams daily and as micrograms per milligram of creatinine, for comparison with the values reported by Williams and his associates. It must be emphasized that we have not isolated the taurine from the urine. These data are determined from the position of the spots on

chromatographic analysis of urine compared with those produced by taurine added to normal urine, the common method used in these analyses. A number of such taurine spots were excised from the chromatogram, and the filter paper was leached. Organic sulphate was found in the leach water; traces of inorganic sulphate were found in control analyses of the filter paper and reagents, but no organic sulphate was found. It appears that taurine, or a similar substance containing oxidized sulphur, is consistently excreted in larger than normal amounts by children with scoliosis. Hence, the word "taurine" in this discussion is used to refer to a soluble organic compound containing oxidized sulphur, which reacts under chromatographic analysis of urine in the same manner as does taurine, and which probably is taurine.

The mean total daily taurine values for the sixteen scoliotic children varied from sixty-seven to 168 milligrams, or sixty-seven to 272 micrograms per milligram of creatinine. Of the values for single twenty-four-hour urine specimens, only two were less than thirty milligrams; the highest daily excretion observed was 246 milligrams. Ten of the sixteen children habitually excreted more than 100 milligrams of taurine daily. Measured in relation to creatinine excretion, thirteen, or 81 per cent., excreted more than seventy-five micrograms of taurine per milligram of creatinine in contrast to one (2 per cent.) of the fifty-two normal subjects excreting this large an amount of taurine.

As a considerable proportion of these children also excreted cysteic acid or methionine sulphoxide, or both, as well as excreting taurine, the loss of sulphur amino-acid derivatives is relatively high. Determination of sulphur partition in the urine gave values wholly within a normal range, as normal range is commonly noted. The presence of urinary taurine, cysteic acid, and methionine therefore represents a perversion of sulphur excretion rather than a simple increase in amount of urinary sulphur in children with idiopathic scoliosis.

SUMMARY

Metabolic studies of calcium, phosphorus, and nitrogen in children with moderate to severe idiopathic scoliosis have been carried out. The findings demonstrated no clear-cut abnormality in mineral metabolism, but did show a serious disturbance in catabolism of protein with excessive wastage of nitrogen through the urine. The metabolic error also appears to involve derivatives of sulphur-containing amino acids. The scoliotic children tended to excrete a larger number of essential amino acids than did normal children of the same age range.

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THE BIOMECHANICS OF FRACTURE HEALING

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INTRODUCTION

It is well known that the course of fracture healing is closely related to the method of treatment and that the results generally vary with the method of fixation. Little is known, however, of the relationship between the method of fixation and fracture healing or of the relationship between fracture healing and biomechanics. The authors believe that the healing of fractures is controlled chiefly by the mode of fixation of the fracture. There is little information concerning the relationship of healing to fixation because most studies have been by clinical and roentgenographic means and because of the difficulty in obtaining the histopathological material.

A few comparative observations of fracture healing in human patients or in animals have been made from the standpoint of biomechanics; and, although authorities, as will be shown, do not altogether agree, Schaffer, Block, Lauche, and Asada have stated that there exists an essential difference in the healing process in human patients and that in animals, the former being by intramembranous ossification and the latter being by enchondral ossification.

Since the publication of Wolff's law, various theories have been postulated regarding the correlation between physical factors and the structure of osseous tissues. The relationship of physical factors to callus differentiation has also been considered in the problem of bone repair; yet many difficult problems still remain to be investigated. Among these is the problem of the effect of mechanical factors on bone repair.

Mechanical factors produced at the fracture site involve many components, of which muscle actions internally and the mode of fixation externally are the most important. Although it is difficult to control an experimental condition involving so many physiological variables, it is possible to analyze the biomechanical factors by observing the usual clinical methods of fixation.

Krompecher divided the mechanical factors involved at the fracture site into compressive and tensile forces. According to him, cartilage appeared at the fracture site when compression had been applied, and ossification occurred by enchondral bone formation; fibrous connective tissue, displaying intramembranous bone formation, appeared under tensile force. Eggers and Schindler stated recently, in their investigation of the effects of mechanical factors upon the healing of osseous tissues, that "contact compression" is most important.

It is recognized that other important factors, such as minerals, hormones, and vitamins, affect fracture healing; however, any study dealing with chemical substances only may be of little value, since, in our opinion, the influence of biomechanics upon callus differentiation outweighs the influence of chemical substances.

METHOD

Healthy rabbits, which weighed about 2,000 grams, were selected for the experiment. A simple transverse fracture was produced in the middle third of the tibia by means of a thin handsaw, great care being taken to minimize injury to the soft tissues and to the periosteum and to remove bone fragments. Into each half of the tibia, two stainless-steel wires were inserted parallel with each other and perpendicular to the bone shaft, so that the four wires lay in the same plane. Fixation was done by one of the following methods:

1. *Firm controlled fixation:* The four wires were secured by metal plates and screws.

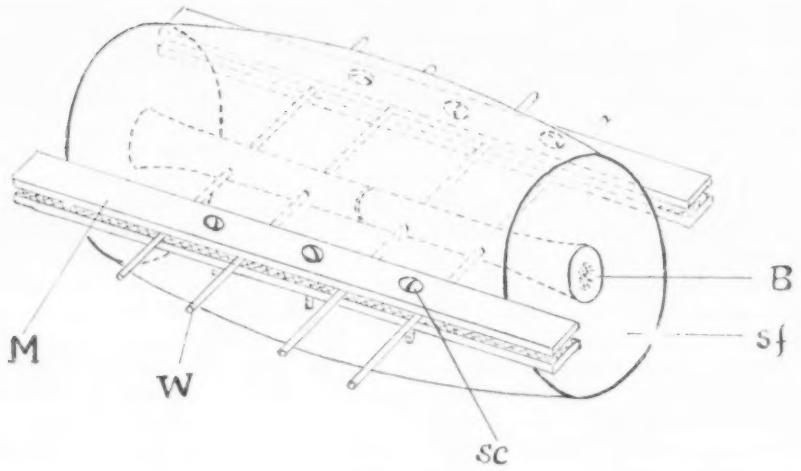

FIG. 1

Firm controlled fixation. *B*, bone; *M*, main plate; *W*, wire; *sf*, soft tissue; and *sc*, screw.

The plate was polished on one surface and was roughened on the other. The rough surfaces were apposed in order to increase friction between the plates and wires. Biomechanical factors were limited to local muscle action, which produced lateral compression of the hematoma and granulation tissue; artificial forces were eliminated. If a cast had been added, muscle action was further decreased (Fig. 1).

2. *Loose controlled fixation:* The screws were loosened slightly and the plates, with the smooth surfaces apposed, were brought almost into contact with the skin. The supplementary plates were then tightly fixed outside the main plates (Fig. 2). Since the wires in each tibial fragment could move up and down to some extent in one plane between the main plates, the fracture fragments were slightly movable along the longitudinal axis.

3. *Compressive fixation:* A heavy rubber band was placed around the wires on each side before the screws were tightened, and firm controlled fixation was applied (Fig. 3).

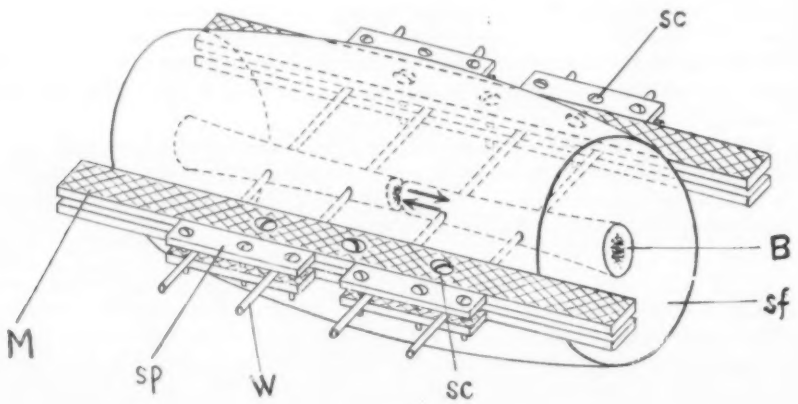

FIG. 2

Loose controlled fixation. *B*, bone; *M*, main plate; *sc*, screw; *sp*, supplementary plate; *W*, wires; and *sf*, soft tissue.

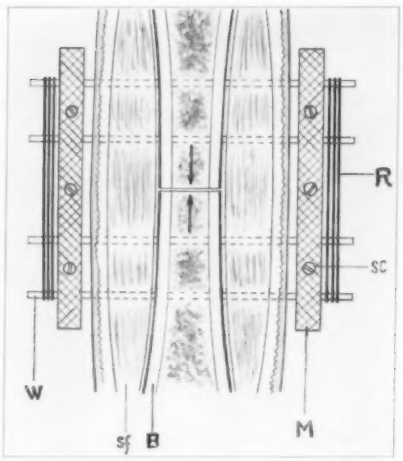

FIG. 3

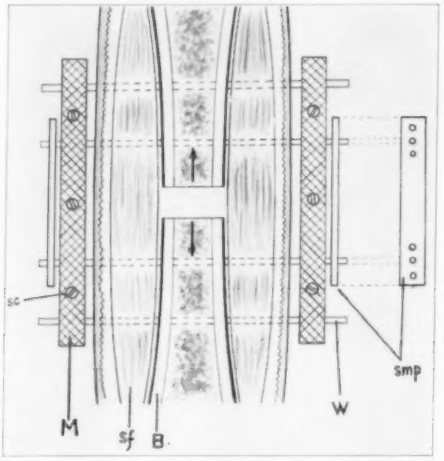

FIG. 4

Fig. 3: Compressive fixation. *R*, rubber ring; *B*, bone; *M*, main plate; *W*, wires; *sf*, soft tissue; and *sc*, screw.

Fig. 4: Extensile fixation. *smp*, small metal plate; *B*, bone; *M*, main plate; *W*, wire; *sf*, soft tissue; and *sc*, screw.

Fig. 5: Spring fixation. *S*, spring; *B*, bone; *M*, main plate; *sp*, supplementary plate; *W*, wire; *sf*, soft tissue; and *sc*, screw.

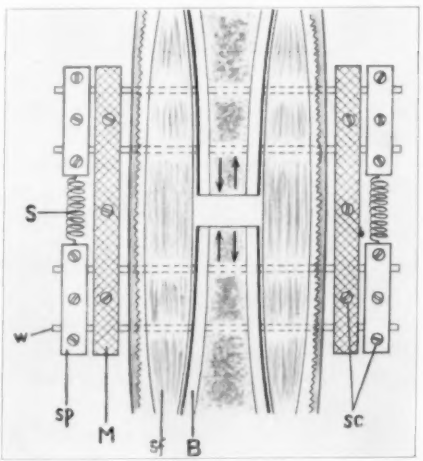

FIG. 5

The compressive force was found to be 500 to 600 grams on each side. In some cases, firm controlled fixation was used for three to seven days, followed by compressive fixation. The object of this procedure was to determine the influences of compression on the organizing tissues, but not on the fracture surfaces of bone.

4. *Extensile fixation:* An extensile or separating force was produced at the fracture site. The distance between the proximal and distal wires was increased slightly by the insertion of a small metal plate between them on each side; and firm controlled fixation was applied (Fig. 4). In some cases, the length of the small metal plates was increased by about one millimeter every four to seven days, and the influence of the intermittent increase of extensile force was studied. In other cases, after three to seven days of firm controlled fixation, compressive fixation and extensile fixation were applied alternately at intervals of two to three days each in order that healing under alternating methods of fixation might be observed.

5. *Spring fixation:* After loose controlled fixation had been applied, a small spring of measured elasticity (about 500 grams) was attached to the proximal and the distal lower supplementary plates on each side (Fig. 5). The hematoma or the granulation tissue at the fracture site was thus subjected to varying degrees of compression, influenced either by muscle action or by body movement. When there was no muscle action (resting state), the expansive power of the spring acted as a distracting force; but, when muscle contracted, the action of the spring was overcome and compression occurred at the fracture gap. The organized tissue was intermittently compressed.

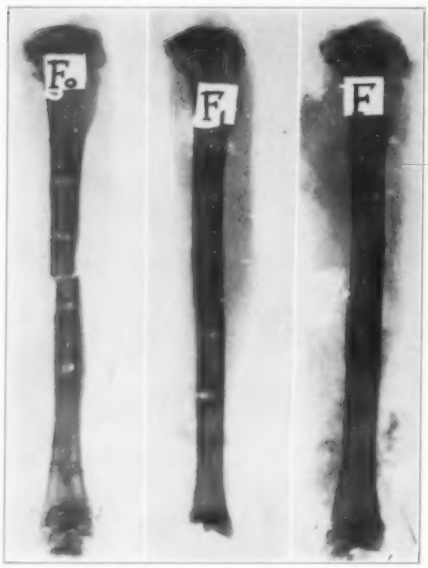

FIG. 6

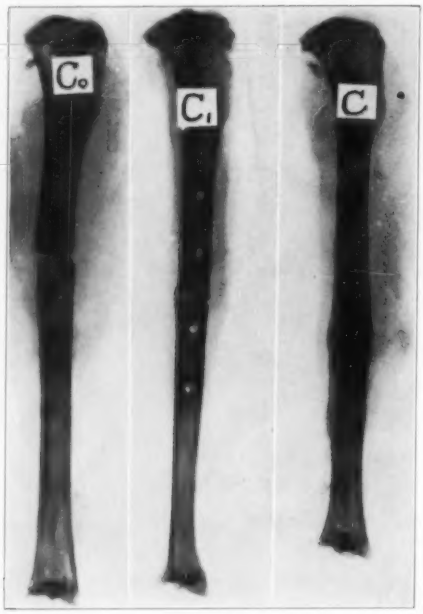

FIG. 7

Fig. 6: Roentgenograms showing callus of type *F*. F_0, one week after fracture; F_1, two weeks after fracture; *F*, six weeks after fracture.

Fig. 7: Roentgenograms showing callus of type *C*. C_0, two weeks after fracture; C_1, three weeks after fracture; *C*, six weeks after fracture.

A sixth type of fixation, that producing shearing force, will be described in detail in the section dealing with pseudarthrosis.

After the biomechanical factors present in the usual methods of treating human fractures had been analyzed, an attempt was made to isolate the various components. The six methods of fixation described were planned to clarify the relationship of each component to the healing process as a whole.

Of more than 250 experimental animals, between thirty and forty showed postoperative infection, malnutrition, unexpected local injuries, or mechanical failure of fixation; these were excluded. About thirty to forty animals in each group treated by one of the six methods of fixation were considered to be statistically significant.

After the operation, the animals were sacrificed at various intervals as follows: (1) one, two, three, and four days, (2) one, two, three, and six weeks, and (3) a few at two to three months. The fractures were studied roentgenographically and were examined histologically.

RESULTS

Roentgenographic Findings

As seen roentgenographically, various types of callus formation appeared during the course of healing. Unusual cases, such as transverse or angular displacement, were excluded.

One hundred and twenty animals were studied, of which ten were treated with loose controlled fixation, thirty with firm controlled fixation, twenty-two with compressive fixation, thirty-two with extensile fixation, and twenty-six with spring fixation.

Callus was divided into four types according to morphological characteristics, such as shape and mass, and was labeled *F*, *C*, *E*, and *S*.

The terms *anchoring callus*, *bridging callus*, *uniting callus*, and *sealing callus*, as defined by Weinmann and Sicher, were used to describe the different types of callus.

1. *Type F* (thirty-three animals). In the early stage of healing, a small amount of flat external callus appeared along the shaft of both fragments. Bridges (Fig. 6, F_1) were formed about two weeks after operation. After six weeks (Fig. 6, *F*), the external callus was small, flat, and well defined; the fracture line was barely visible.

2. *Type C* (thirty-six animals). About two weeks after operation, a larger external callus than that of type *F* appeared at the fracture site. This immature callus disappeared, leaving a V-shaped depression at the fracture site perpendicular to the bony surfaces (Fig. 7, C_0). Within three weeks, bridging callus, with a slight elevation, formed at the fracture site (Fig. 7, C_1). After about six weeks, the external callus resembled a small, gently sloping elevation, and the fracture line was barely visible (Fig. 7, *C*).

Another type of callus formation, that between type *F* and type *C*, which was termed type *F'* (six animals) (Fig. 8), resembled type *F* in shape, although the amount of external callus was a little greater, as was that in type *C*. Six fractures with

FIG. 8

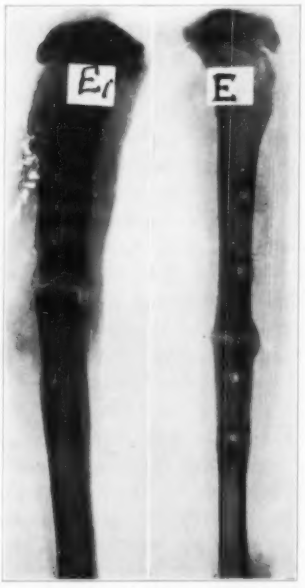

FIG. 9

FIG. 10

Fig. 8: Roentgenograms showing callus of type *F'*. F'_1, two weeks after fracture; *F'*, six weeks after fracture.

Fig. 9: Roentgenograms showing callus of type *E*. E_1, three weeks after fracture; *E*, six weeks after fracture.

Fig. 10: Roentgenograms showing callus of type *S*. S_0, three weeks after fracture; S_1, four weeks after fracture; *S*, six weeks after fracture.

TABLE I

THE INCIDENCE OF EACH CALLUS TYPE FOR EACH MODE OF FIXATION

Callus	Firm Controlled Fixation		Compressive Fixation		Extensile Fixation		Spring Fixation		Loose Controlled Fixation		
	(*No. of Cases*)	(*Per cent.*)	(*No. of Cases*)	(*Per cent.*)	(*No. of Cases*)	(*Per cent.*)	(*No. of Cases*)	(*Per cent.*)	(*No. of Cases*)	(*Per cent.*)	Total
Type F	20	66.	5	22.	6	19.			2	20.	33
Type C	8	26.	14	64.	10	31.	2	7.	2	20.	36
Type E	2	6.	3	14.	14	43.	6	23.			25
Type S					2	7.	18	70.			20
Type F′									6	60.	6
Total	30		22		32		26		10		120

callus of this type showed smooth healing similar to that of type *F*. This type of bone formation was seen chiefly in animals with loose controlled fixation.

3. *Type E* (twenty-five animals). In the early stage, the callus showed a characteristic beak-shaped formation near each fracture end which greatly resembled bone changes in arthritis deformans. The tips of the beaks lengthened gradually, united after about three weeks, and enclosed a radiolucent spot (Fig. 9, E_1). After about six weeks (Fig. 9, *E*), the external callus showed a mound-like elevation, in which a small radiolucent focus remained. The fracture line was recognizable and showed slight separation.

4. *Type S* (twenty animals). This type of callus was unusual in that there was excessive external callus near the fracture ends; the fracture did not unite even after three weeks (Fig. 10, S_0). The bridging callus appeared from twenty-five to thirty-eight days after the operation. After six weeks (Fig. 10, *S*), an abundant external callus was seen. There still remained ill defined, irregular, heterogeneous radiolucent zones within the callus; the fracture showed slight separation.

The interrelation of these callus types is shown in Figure 11.

The frequency of the occurrence of each callus type for each mode of fixation is shown in Table I.

It appears that the types of callus formation are closely related to the methods of fixation and that each method, except extensile fixation, is associated with a characteristic callus type (Table I). Type *F* is regarded as the characteristic result of firm controlled fixation, type *C* as the result of compressive fixation, and type *S* as the result of spring fixation. In the fractures fixed by

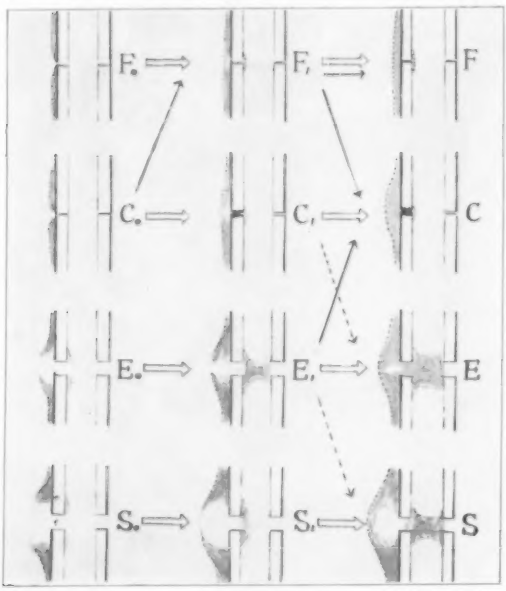

FIG. 11

F_0 progresses through F_1 to *F* as shown by the thick arrow. C_0 reaches *C* through C_1, sometimes arriving at *F* or *C* through F_1 as shown by the thin arrow, and it occasionally arrives at *E* as shown by the broken line. In the same way E_0 progresses through E_1 to *E* or occasionally to *C* or *S*.

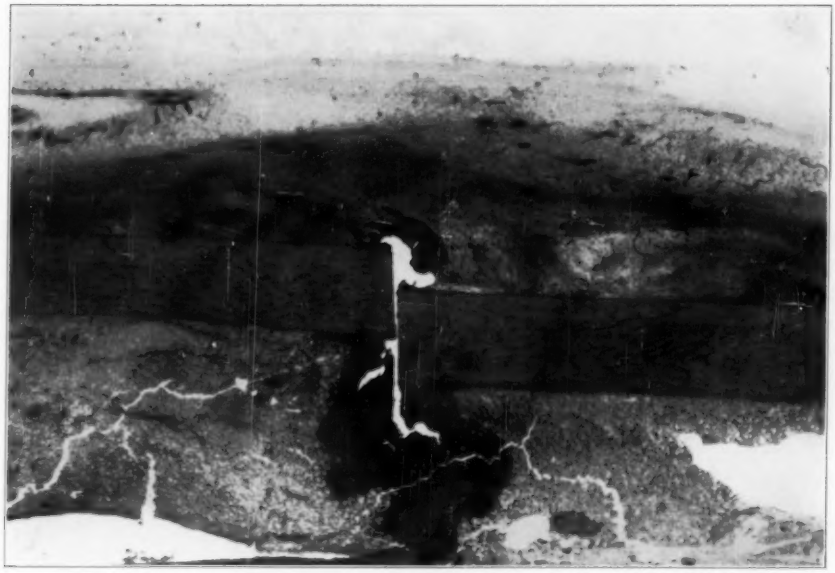

FIG. 12

Photomicrograph (× 17) of cross section of F_0 shown in Fig. 6. External callus is flat, small, arranged along the bone shaft, and disappears gradually at the fracture site which is filled with hematoma and loose connective tissue.

loose controlled fixation, type F', mid-way between types F and C, resulted. The variety of the callus formation resulting from extensile fixation of the fracture seems to be due to the greater mobility allowed by this type of fixation.

Histological Findings

The histological findings, which will be described in relation to the roentgenographic findings, are as follows:

1. *Histology of Type F*

F_0 (Figs. 6 and 12). *External callus:* One week after fracture, the small spaces of the callus had been filled with loose oedematous fibrous connective tissue, containing organizing blood clots (the early stage of bridging callus). A short distance from the fracture, this loose connective tissue became dense and was replaced gradually at the fracture line by a small amount of flat bone which had been produced under the periosteum (anchoring callus). The anchoring callus was composed of ground substances containing many round cells and was surrounded by one to several layers of spindle-shaped cells or oval cells (osteoblasts). Osteoblasts which were arranged in a single layer appeared to be "resting", while those which were arranged in several layers proliferated actively toward the fracture line and often adhered to the fibers of the connective tissue. Ossification was carried out almost exclusively by means of intramembranous bone formation. Chondroid tissue was seldom observed.

F_0. *Internal callus:* The bone marrow at the fracture site and the space between the fracture surfaces was filled with a loose oedematous or slightly dense fibrous connective tissue and hemorrhagic mass. No bone formation was observed, although organization was proceeding.

F_0. *Bone fragments and soft tissues:* No osteocytes were found at the fracture site, there was slight necrosis at the fracture ends, and the soft tissues showed aseptic inflammation.

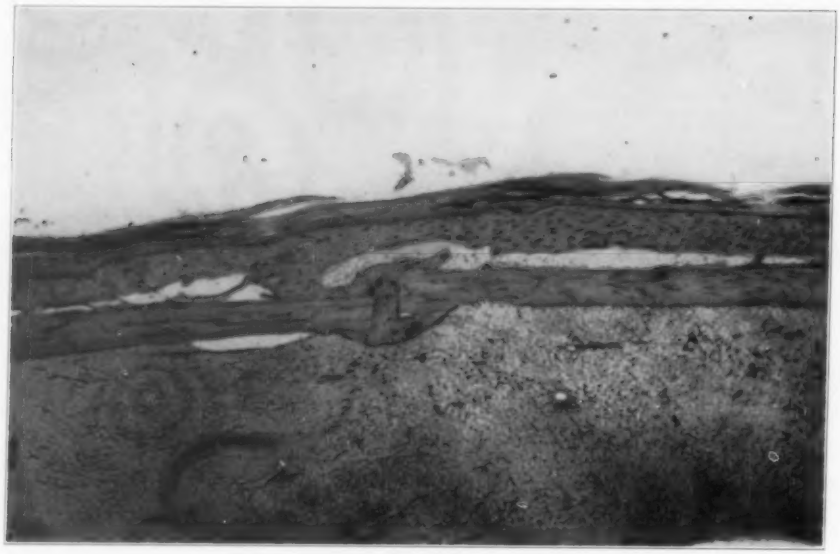

FIG. 13

Photomicrograph (× 17) of cross section of *F* shown in Fig. 6. External callus is flat and small and has a lamellar structure. The fracture ends are firmly united.

F_1 (Fig. 6). *External callus:* Two weeks after fracture, except for a small area of dense fibrous connective tissue at the fracture site, the bridging callus was composed of bony tissue. A very small amount of oedematous connective tissue and blood clot was observed. Lacunar resorption of the newly formed bony tissue by osteoclasts was beginning, in addition to the active growth of bone through the proliferation of osteoblasts.

F_1. *Internal and intermediate callus:* The organization had been completed and the uniting callus was composed of dense fibrous tissue displaying intramembranous bone formation; the sealing callus had disappeared.

F_1. *Bone fragments and soft tissues:* Necrotic bone ends had been absorbed and had been replaced by uniting callus. Inflammatory changes in the soft tissues had almost disappeared.

F (Figs. 6 and 13). *External callus:* Six weeks after fracture, both the anchoring callus and the bridging callus showed the structure of lamellar bone, the trabeculae of which had become thick and uniform.

F. *Internal and intermediate callus:* The ends of the fragments were joined firmly by the uniting callus, which had a lamellar structure. No changes were found in the bone marrow.

F. *Bone fragments and soft tissues:* Normal conditions had been restored.

2. *Histology of Type C*

C_0 (Fig. 7). *External callus:* Two weeks after fracture no essential differences were noted between type C_0 and type F_0, except that in type C_0 the anchoring callus was a little larger and that small foci of chondroid tissue were sometimes found in the bridging callus.

C_0. *Internal and intermediate callus:* Practically the same structure was shown as that in type F_0.

C_0. *Bone fragments and soft tissues:* Necrosis of the cortical ends was a little more conspicuous than that in type F_0.

C_1. *External callus:* Three weeks after fracture, the anchoring callus, showing intra-

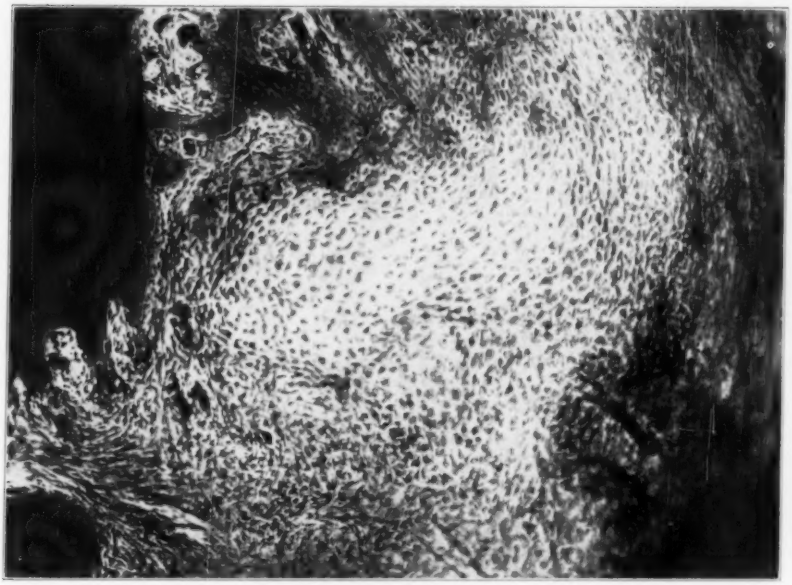

FIG. 14

Callus type C_o (Fig. 7). Small foci of chondroid tissue and absorption of the cortical stump are seen (× 125).

membranous bone formation, was approaching the fracture line along the shaft of the bone. Small foci of cartilage (Fig. 14) near the bridging callus showed enchondral ossification. Reorganization of the hematoma was sometimes a little retarded.

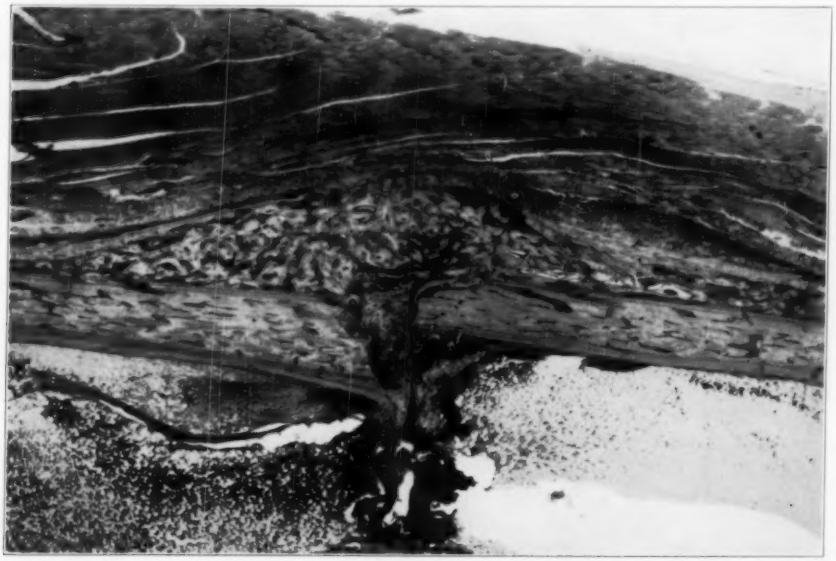

FIG. 15

Photomicrograph (× 17) of cross section of *C* shown in Fig. 7. External callus resembles a low hill. The uniting callus has replaced absorbed portions of the fracture ends. A small sealing callus is seen.

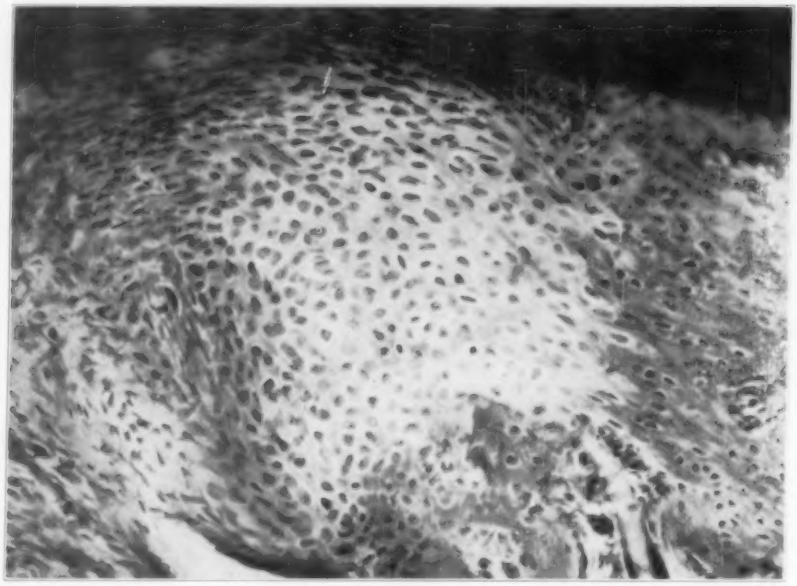

FIG. 16

Direct transformation of chondroid tissue into bone (× 213).

C_1. *Internal and intermediate callus:* The uniting callus usually showed intramembranous ossification and occasionally showed enchondral ossification. A small amount of bony tissue was sometimes recognized in the bone marrow as a result of the intramembranous ossification of the sealing callus.

C_1. *Bone fragments and soft tissues:* The necrotic cortical ends had been absorbed; there were no inflammatory changes.

C (Figs. 7 and 15). *External callus:* Six weeks after fracture, the anchoring callus and the bridging callus showed lamellar bone structure and approached the appearance of what we term secondary bone, that is, bony tissue in which the reconstruction process has been nearly completed.

C. Internal and intermediate callus: The fragments were finally completely united by ossification of the uniting callus and by a small amount of bone in the sealing callus.

C. Bone fragments and soft tissues: These had reverted to normal and showed no degenerative or inflammatory changes.

3. *Histology of Type E*

E_0. *External callus:* The bridging callus was filled with loose oedematous or dense fibrous connective tissue, relatively abundant chondroid tissue, and an organizing hemorrhagic mass. Irregular, beak-like projections of the anchoring callus were almost united or were completely united with the fibrous tissue of the bridging callus.

E_0. *Internal and intermediate callus:* The formation of a fibrous callus was relatively prominent at the fracture gap (uniting callus). Blood clot, oedema, and a small amount of loose connective tissue remained in the marrow cavity (sealing callus).

E_0. *Bone fragments and soft tissues:* Necrotic changes at the fracture ends were slight in comparison with those in type C_0. Muscle fibers were remarkably atrophic, and aseptic inflammation with serofibrinous exudation was present.

E_1 (Figs. 9 and 16). *External callus:* Three weeks after fracture, the bridging callus, composed of fibrous connective tissue and cartilaginous tissue, showed intramembranous and enchondral ossification simultaneously. Occasionally, definite evidence of direct

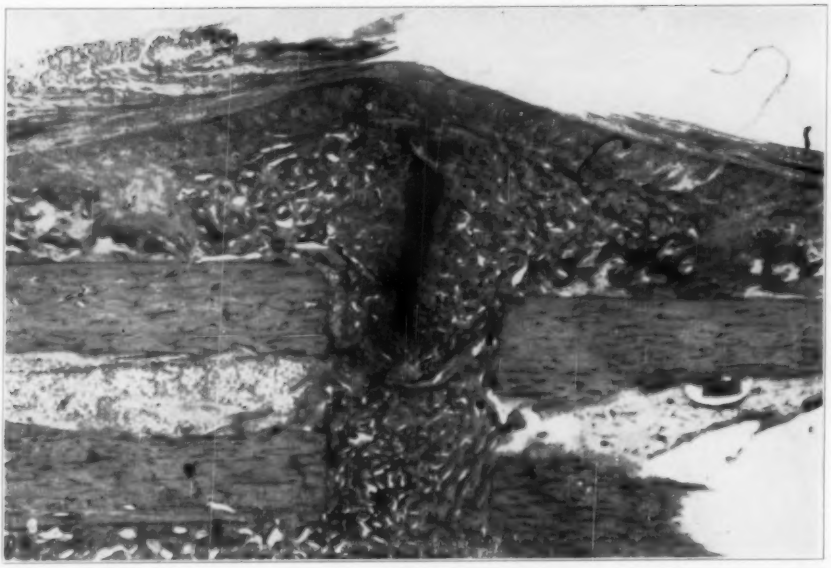

FIG. 17

Photomicrograph (× 17) of cross section of *E* shown in Fig. 9. Within the large bony external callus there is a focus of deeply stained cartilage, consisting of hyperchromic cells which correspond to the radiolucent focus in the roentgenogram.

transformation of the cartilage into bone was found (Fig. 16). The anchoring callus had grown and was approaching the fracture site.

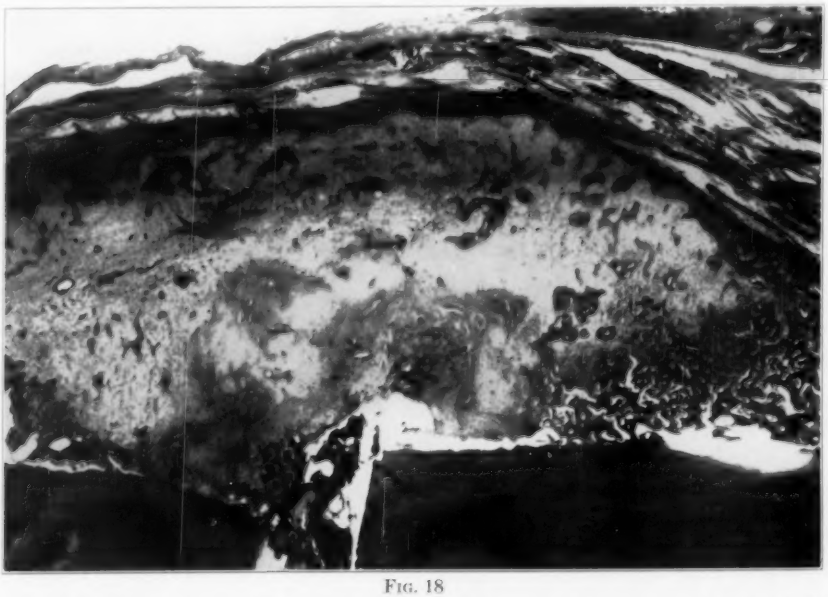

FIG. 18

Photomicrograph (× 17) of cross section of S_o. There was a fairly large amount of chondroid tissue of external callus, this was followed by ossification of the anchoring callus. In the fracture gap hematoma and loose connective tissue are seen.

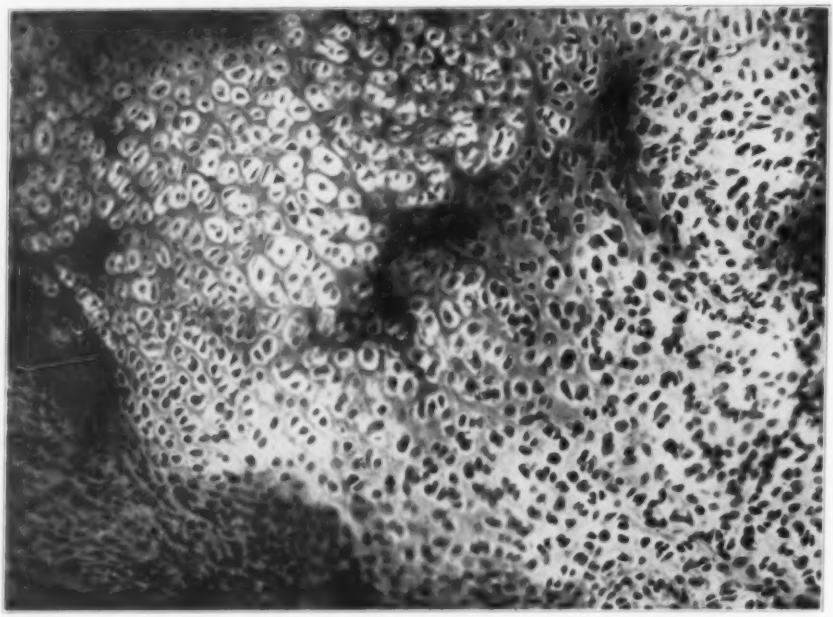

FIG. 19

Photomicrograph (× 170) of material from callus of type S_1 shows vigorous proliferation of chondroid tissue.

E_1. *Internal and intermediate callus:* Fibrous connective tissue of both the uniting callus and the sealing callus was undergoing ossification by intramembranous bone formation. Sometimes fat tissue was observed in the connective tissue.

E_1. *Bone fragments and soft tissues:* The muscle fibers had remained atrophic. The hemorrhagic mass and oedema had disappeared. Often many osteoclasts appeared at the fracture ends and produced extensive lacunar resorption.

E (Figs. 9 and 17). *External callus:* Six weeks after fracture, the anchoring callus and the bridging callus had become mound-like lamellar bone, with the peak of the mound over the fracture, enclosing small foci of hyaline cartilage. Ossification of the cartilage was retarded.

E. Internal and intermediate callus: The uniting callus and the sealing callus showed intramembranous bone formation chiefly.

E. Bone fragments and soft tissues: Atrophic muscle fibers were still seen.

4. *Histology of Type S*

S_0 (Figs. 10 and 18). *External callus:* Three weeks after fracture, there were oedematous, loose fibrous connective tissue and a hemorrhagic mass, as well as a fairly large quantity of chondroid tissue, at the fracture site (bridging callus). The anchoring callus was some distance from the fracture and had grown, with irregular projections, at right angles to the bone shaft.

S_0. *Internal and intermediate callus:* Hematoma and oedema were prominent, organization was delayed, and cartilaginous tissue was found in both the uniting callus and the sealing callus.

S_0. *Bone fragments and soft tissues:* Necrosis of the fracture ends was severe.

S_1 (Figure 19). *External callus:* Four weeks after fracture, the bridging callus was almost completely composed of cartilage and chondroid tissue which often proliferated vigorously. The anchoring callus was about to enclose the cartilage of the bridging callus,

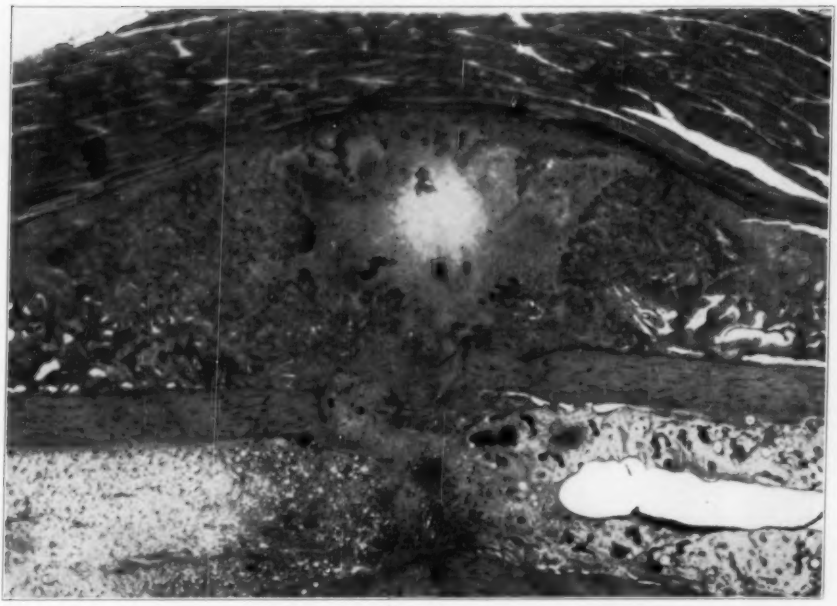

FIG. 20

Photomicrograph (× 17) of cross section of type *S* shown in Fig. 10. Within the mound-shaped external callus there remains an area of cartilage which corresponds to the radiolucent area in the roentgenogram. Bone fragments are barely joined by the uniting callus and the sealing callus which show formation of new bone.

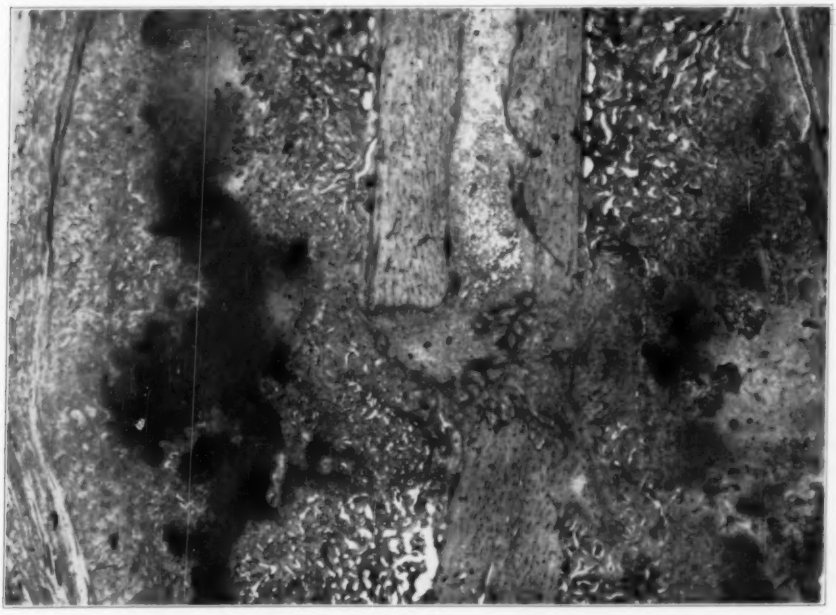

FIG. 21

Photomicrograph (× 17) of another section of the cross section of type *S*. Bony union is almost attained by the uniting callus and the sealing callus. Within the cartilage of the external callus there is a deeply stained focus of hyperchromic cells.

FIG. 22

Photomicrograph (× 20) of cross section of *S*, six weeks after fracture. Within the bony tissue of the uniting callus and the sealing callus, there is a deeply stained focus of abnormal calcification. On each side, there is a deeply stained cartilaginous area in the external callus. The one on the left encloses a small homogeneous crescent-shaped spot which shows softening necrosis.

but the vigorous proliferation of the cartilage had compressed and raised the anchoring callus. A mound had, therefore, been built up at the fracture site, the outside of which was composed of the bony tissue of the anchoring callus and the inside of which was made up of cartilage originating in the bridging callus. At the peak of the mound, ossification was temporarily greatly retarded.

S_1. *Internal and intermediate callus:* An abundant mass of cartilage and fibrous tissue had formed, the former chiefly in the uniting callus and the latter chiefly in the sealing callus.

S_1. *Bone fragments and soft tissues:* The soft tissues at the fracture site had been lifted by the proliferating cartilage of the bridging callus. Between the soft tissues and the cartilage, oedematous myxomatous spaces appeared with the formation of many delicate capillaries.

S (Figs. 10, 20, 21, and 22). *External callus:* Much bony tissue with lamellar structure was seen in the anchoring callus and the bridging callus. Lacunar resorption by osteoclasts was seen here and there. Throughout this bony tissue were many foci of cartilage which showed enchondral ossification, necrosis, and softening.

S. Internal and intermediate callus: The bone marrow was almost enclosed by the bony tissue of the sealing callus, in which cartilage remained. The uniting callus had several foci of cartilage within the bony tissue, which often showed softening and necrosis.

S. Bone fragments and soft tissues: The oedematous and myxomatous spaces between the external callus and the soft tissue had been replaced by dense connective tissue.

The first step in fracture healing is aseptic inflammation around the hematoma. In the early stages, the callus formation is essentially the same, resulting from the different

types of fixation, but later callus of specific types is developed. In type *F*, the external callus was composed of a small amount of flat, fibrous connective tissue which showed intramembranous bone formation. In type *C*, callus formation was a little larger and was occasionally mixed with chondroid tissue. In type *E*, cartilaginous callus became more prominent and the fibrous connective-tissue callus was abundant. The authors believe that direct transformation of the cartilaginous tissue into bone occurs, although this is denied in some textbooks [2]. Type *S* was a large callus which had been produced chiefly by cartilaginous tissue with many regressive changes.

Summary of Roentgenographic and Histological Investigations

1. A radiolucent area in the anchoring callus indicates the presence of abundant cartilage, as in type *E* and type *S* in which abundant mound-like external callus appear. Cartilaginous callus often shows degenerative changes histologically.

2. A V-shaped defect in the external callus usually indicates fibrous connective tissue of the bridging callus. External callus in this instance is not usually prominent and is flat in shape.

3. Callus, small in size, is composed chiefly of a fibrous connective tissue which shows intramembranous bone formation. Roentgenographically, it is seen as a flat or slightly swollen bony callus along the shaft of the bone, as in types *F*, *C*, and *F'*.

4. From the standpoint of increasing size and complexity, the callus types

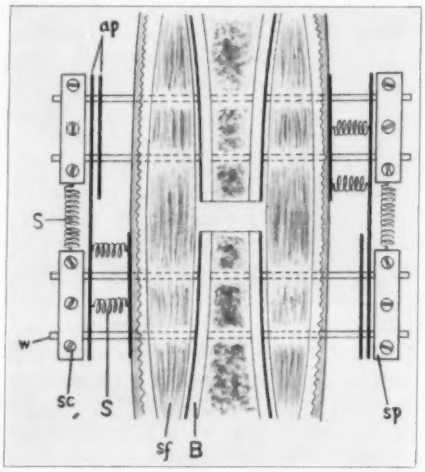

FIG. 23-A

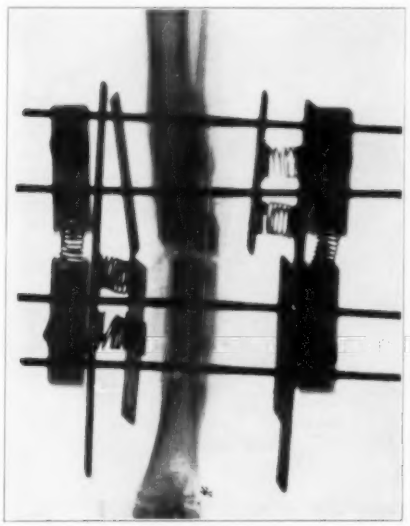

FIG. 23-B

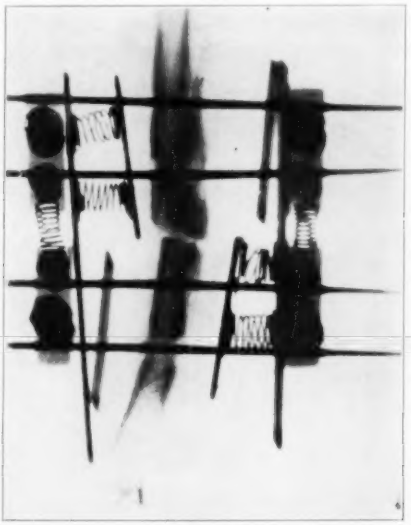

FIG. 23-C

First method of experimental pseudarthrosis. Note the alternate position of springs in Figs. 23-B and in 23-C. (*ap*, accessory plates; S, springs.)

are arranged in the following order: *F*, *F'*, *C*, *E*, and *S*. Type *F* is the simplest, and type *S*, the largest, the most irregularly shaped, and the most complex.

Among these callus types, type *F'* is considered by the authors to be the best in regard to fracture healing. As regards the external callus, type *C* is stronger mechanically than type *F* because of more abundant callus, although it is followed by more extensive necrosis of the fracture fragments due to compression.

PSEUDARTHROSIS AND BIOMECHANICS

From the roentgenographic and histological findings, it is apparent that the processes of experimental fracture healing are closely related to the method of fixation and that characteristic variations occur according to the biomechanical factors involved. The results of spring fixation are especially interesting as fractures thus fixed apparently show not only delayed union but also indications of the development of pseudarthrosis. Hence, the following experiments were done on the supposition that genuine pseudarthrosis might develop if shearing force were added to spring fixation.

Production of Pseudarthrosis

Two methods of producing pseudarthrosis experimentally were used:

1. In this experiment, ten animals were used; pseudarthrosis was successfully produced in six animals. A transverse fracture of the tibia was produced and spring fixation was applied. In two weeks, when the fracture gap had been filled with extensive cartilage and callus and the hematoma was well organized, another set of springs was fitted between the accessory plates in order that shearing forces might be produced at the fracture site. Two springs were applied on the proximal part of the fractured bone on one side, and two springs were applied on the distal part on the opposite side (Figs. 23-A, 23-B, and 23-C). The horizontal springs were detachable. Each spring had a maximum expansive power of 150 grams; consequently, the pressure which acted on one fragment was always 300 grams or less. The positions of the springs were alternated each day; the two springs which had been applied to one side were transferred to the opposite side on

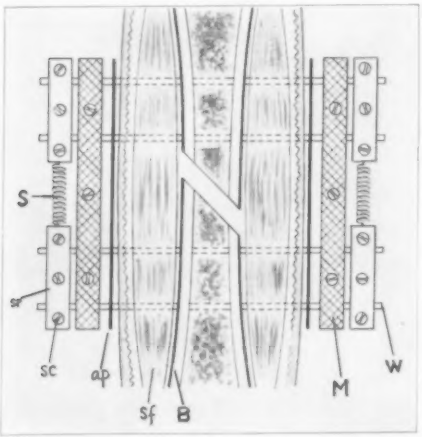

FIG. 24

FIG. 25-A

Fig. 24: Second method of experimental pseudarthrosis.

Fig. 25-A: Postero-anterior roentgenograms illustrating experimental pseudarthrosis (Case 1). Ten weeks after fracture.

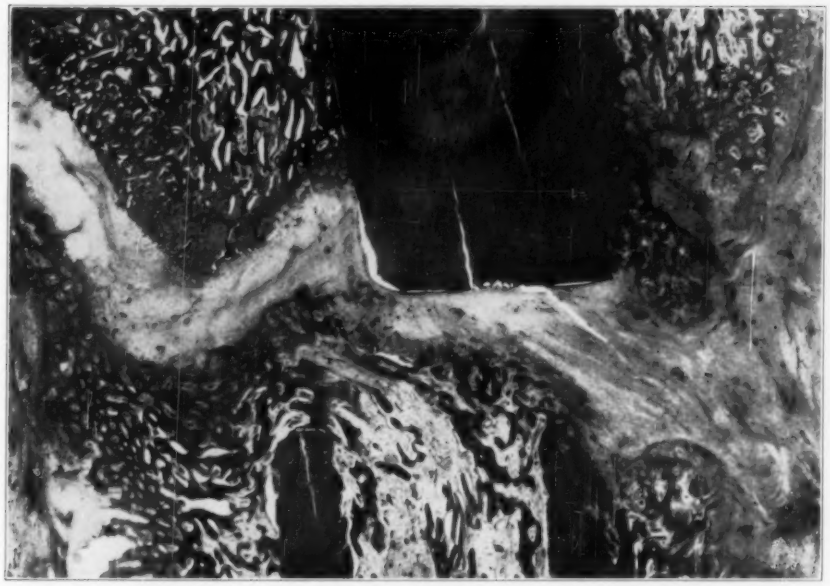

FIG. 25-B

Photomicrograph (× 15) of cross section of the pseudarthrosis shown in Fig. 25-A.

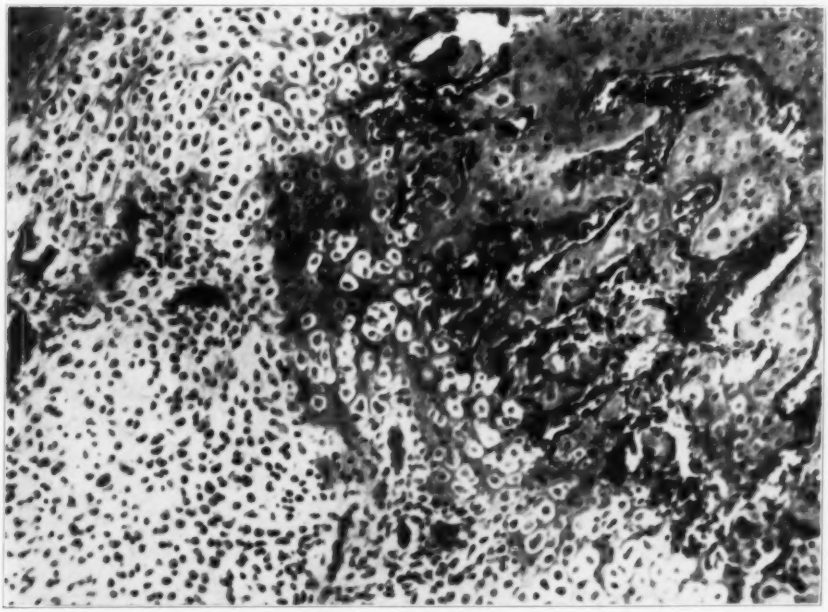

FIG. 25-C

Photomicrograph (× 170) of specimen from cross section of pseudarthrosis shown in Fig. 25-B illustrating enchondral ossification.

the next day. Thus, there was an artificially produced intermittent shearing force at the fracture site.

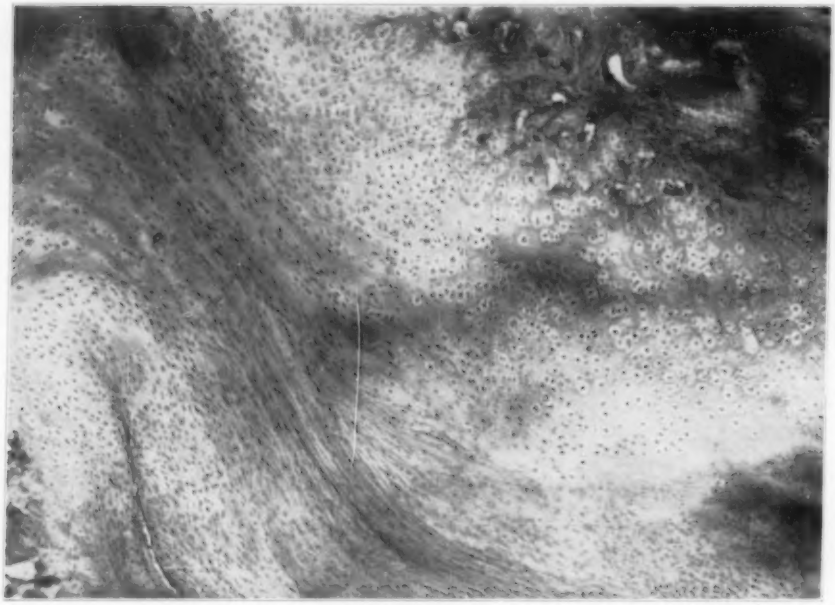

FIG. 26

Degeneration of cartilage into thick fibrous tissue (bridging callus) (× 125).

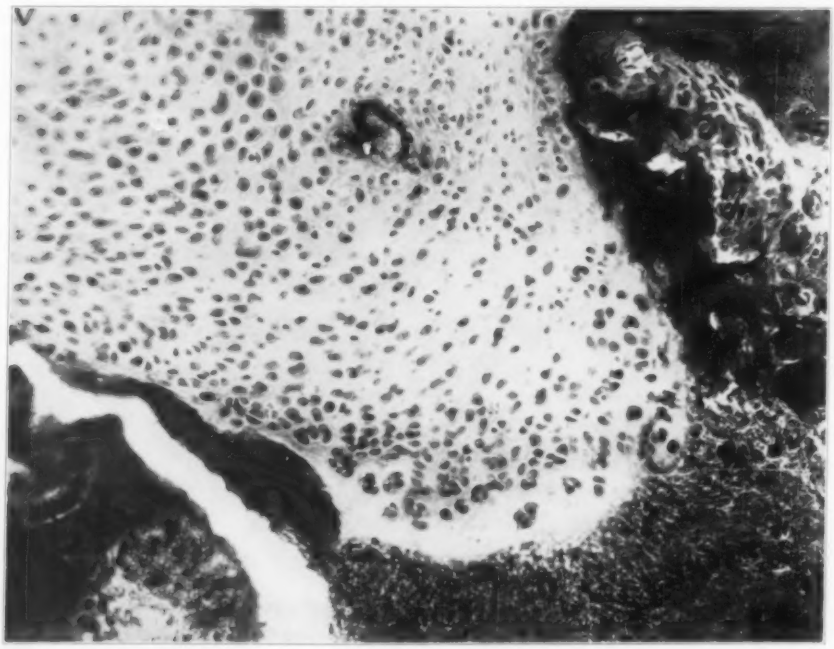

FIG. 27

Small area of softening necrosis in cartilage with pyknotic nuclei (× 125).

FIG. 28

Fracture gap is filled with cartilage. Enchondral ossification (right) and necrosis (upper left) are seen. Adjacent bone tissue shows evidence of linear resorption (× 85).

2. In the second experiment, six animals were used and pseudarthrosis was successfully produced in four. In order to allow the shearing force to occur automatically at the fracture site through movement and local muscle contraction, an oblique fracture was made. Spring fixation was applied. Thus intermittent shearing force could occur on the fracture plane as a component of the compressive forces produced by muscle contraction.

Results

The animals were all observed for two to three months, and bony union was never attained. Roentgenographic and histological findings in two representative animals are as follows:

Case 1 (ten weeks after fracture, first method): As seen roentgenographically (Fig. 25-A), there was excessive external callus. The marrow of the upper fragment was closed with internal callus, and a radiolucent zone was seen at the site of the fracture gap. On histological examination, it was seen that, in spite of an abundant mass of external and internal new bone, the fracture gap was still filled with cicatrized tissue and with cartilage which showed various degrees and types of differentiation (Fig. 25-B). Remarkable enchondral ossification was being carried out at the point of transition of the cartilage to the new bone (Fig. 25-C), but elsewhere spotty degeneration of the cartilage into thick fibrous tissue was seen (Fig. 26). In other parts, the cartilage cells showed pyknosis of the nuclei (Fig. 27) which was often combined with softening necrosis of the tissue. There was found, in such areas, evidence of disturbed enchondral ossification or an appearance of new bone and cartilage being distinct from one another (Figs. 28 and 29). Furthermore, in other specimens, areas of softening were recognized here and there, frequently with myxomatous degeneration (Fig. 30). In addition, incompletely ossified foci of cartilage tissue (Fig. 31) and linear resorption—that is, resorption or destruction of bony tissue without the participation of osteoclasts or fibroblasts—of the new bone are frequently seen (Figs. 28 and 32).

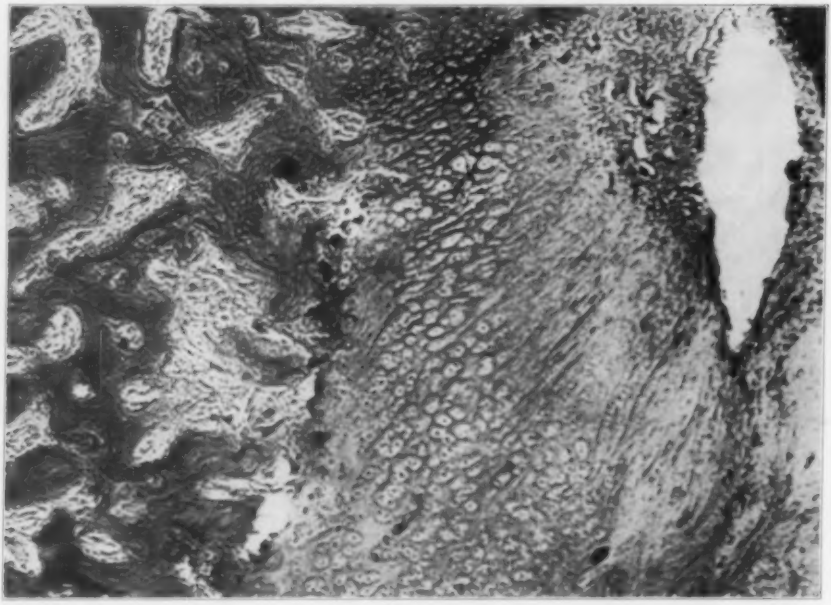

FIG. 29

Softening necrosis of the cartilage is accompanied by crevice formation and cicatrization (upper right). Degeneration of the cartilage is also seen, with little tendency to enchondral ossification. It remains distinct from new bone (× 125).

FIG. 30

Myxomatous degeneration is seen adjacent to the crevice formation (× 170).

Most areas in the transition of the new bone to cicatrized tissue showed cessation of bone formation.

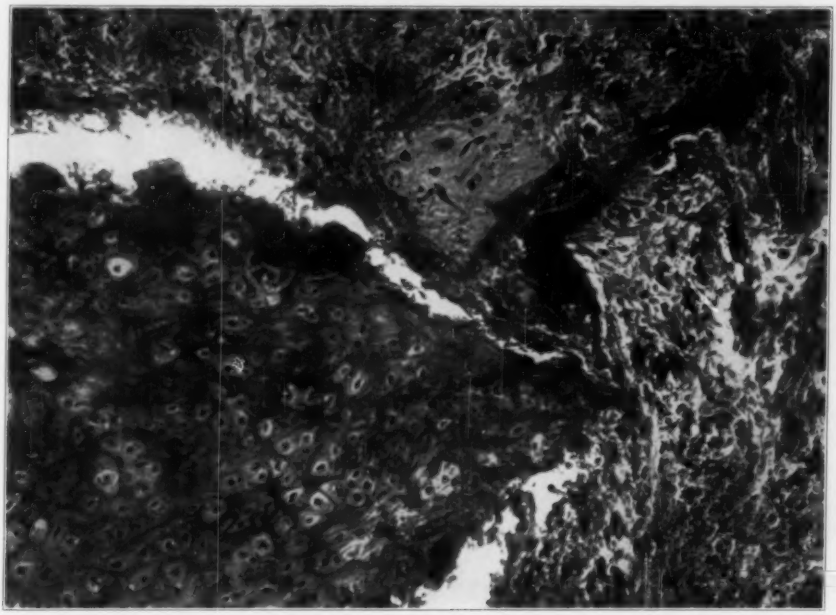

FIG. 31

Incompletely ossified focus of cartilage (lower left) (× 170).

FIG. 32

Linear resorption of bone (left) (× 85).

FIG. 33
Photomicrograph (× 10) of cross section of pseudarthrosis in Case 2, nine weeks after fracture.

Case 2 (*nine weeks after fracture, second method*): Roentgenographically, a comparatively large external callus had been produced at the end of the upper fragment. Internal callus had closed the marrow cavity. The fracture was recognizable as an oblique, transparent, band-like zone. Histologically (Fig. 33), new bone was abundant externally and internally at the end of the upper fragment, but it was comparatively scanty on the lower fragment. The fracture was filled chiefly with cicatrized fibrous tissue, with a small amount of hyaline cartilage in which degeneration was seen here and there. Enchondral ossification was partly visible. For the most part, however, ossification was markedly disturbed and there was no tendency to bony union.

The authors' experience with human pseudarthrosis has been presented in detail elsewhere [18]. Based on microscopic examinations, it is their opinion that pseudarthrosis in human patients probably results from complicated, abnormal callus differentiation, with both new-bone formation and regressive changes, such as degeneration, necrosis, and linear resorption of the new bone.

The histological findings in experimental pseudarthrosis are the same as those found in pseudarthrosis in human patients. Numerous attempts have been made to produce pseudarthrosis experimentally but without success. There seem to be many factors in the etiology of pseudarthrosis, and among them are the general factors of malnutrition and age, and such local factors as inadequate immobilization, wide separation of fragments, insufficient blood supply, interposition of soft tissue, and infection.

The term "defect pseudarthrosis" is used to describe non-union due to exhaustion of the regenerative power of the bone, whereas the term "genuine pseudarthrosis" is used when non-union appears to be due to abnormal callus differentiation. Experimental studies of the production of defect pseudarthrosis and pseudarthrosis due to interposition of soft tissue have been reported as successful. These studies, however, contribute little to the understanding of genuine pseudarthrosis. Many aspects of the latter require further investigation; among these aspects are mechanical factors, the importance of which has

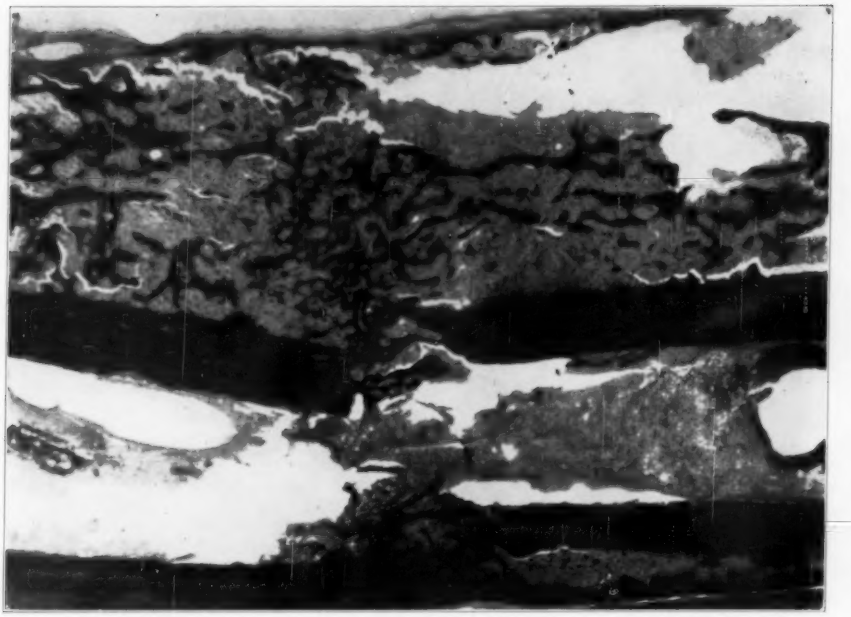

FIG. 34

Photomicrograph (× 25) of cross section of fracture site six weeks after fracture. Muscles were cut off at their distal attachment to the bone. Reorganization is much retarded with wide lacunae and thin bone trabeculae.

been emphasized by Rehn, Brandt, and Pauwels. Although many clinicians are of the opini t shearing force may be the most important factor in the etiology of pseudarthros ar as we can learn from a careful review of medical literature up to the present time, no one has been able to prove this experimentally. Our experiments emphasize the importance of this force in the production of experimental pseudarthrosis.

CALLUS DIFFERENTIATION AND BIOMECHANICS

Callus differentiation is largely controlled qualitatively, quantitatively, and morphologically by local biomechanical factors. The close connection between callus differentiation and biomechanics will be described systematically from the pathological standpoint; Krompecher's investigation of this problem is very instructive. The circulatory disturbances, especially the formation of the hematoma, are followed by proliferation of embryonic or mesenchymal tissue, which is one matrix of new bone, and is called "procallus". Healing, therefore, starts at procallus and passes through the stages of primary and secondary bone to arrive at final healing. The whole process is greatly influenced by mechanical factors.

A. *Callus Differentiation under a Biomechanically Neutral Condition*

In our experiments, biomechanical neutrality was considered to have been obtained when firm controlled fixation was present, when injuries of the soft tissues, including the periosteum, were only of the slightest degree, when fracture healing was in a relatively early stage, when the muscles had not recovered contractile action, and when a hydrostatic equilibrium was maintained. However, it is very difficult to obtain a condition entirely free from any mechanical force because the action of the muscles and the soft tissues can seldom be entirely eliminated.

FIG. 35

Young trabeculae among the layers of spindle-shaped cells (forty-eight hours after fracture) (× 400).

In order to study the influence of muscle action, the healing of fractures immobilized by firm controlled fixation was observed after the distal attachment of overlying

FIG. 36

Three osteoclasts with abundant cytoplasm and several nuclei are seen in the lacunae (× 425).

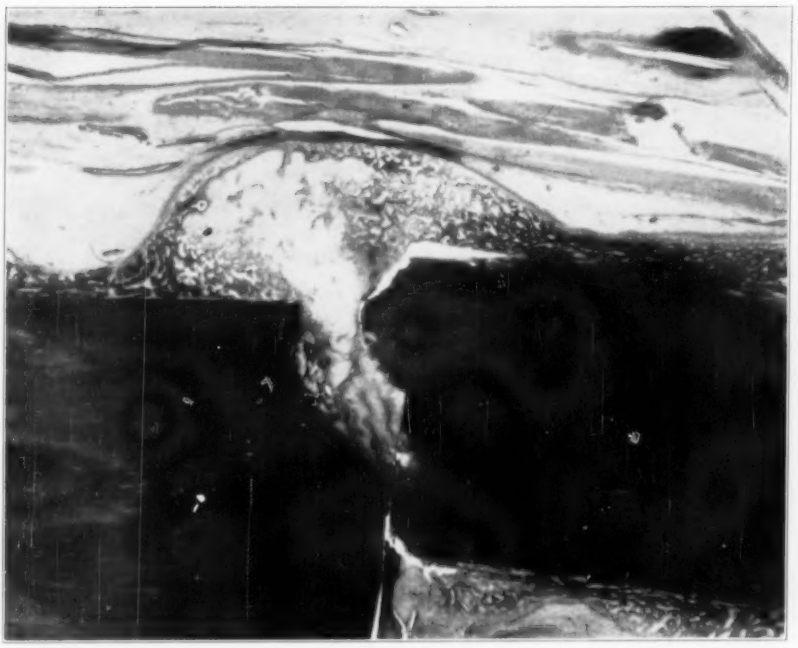

FIG. 37

Expansive proliferation of cartilage callus. Oedematous spaces are seen at both sides of external callus under the muscle tissue (× 13).

muscles had been cut or after the corresponding nerve had been cut. Ten animals were used. Although bony tissue was formed with many osteoblasts and osteoclasts and without recognizable regressive changes, the reorganization was extremely retarded (Fig. 34). It is not certain, however, that the influence of cutting of the distal attachment of the overlying muscles or nerve upon fracture healing is strictly mechanical.

Histological findings observed under such a condition are as follows: Spindle-shaped cells of the mesenchymal tissue proliferated vigorously and formed compact cell layers which were arranged parallel with the shaft (in twenty-four to seventy-two hours), while heterogenous substances appeared among the cell layers (Fig. 35). These substances contained round cells and were surrounded by one layer of oval cells and osteoblasts, which were derived from mesenchymal cells. With the proliferation of the osteoblasts, the bony trabeculae became larger and more irregular and began to enclose lacunae consisting of loose connective tissue and small blood vessels. A short time later, some osteoclasts, containing a large amount of cytoplasm and several nuclei, appeared in the lacunae and began to resorb the bony trabeculae (Fig. 36). Thus the formation and modification of bony substance occurred nearly synchronously, and it seems to us that bone formation under these conditions occurs by the direct transformation of mesenchymal cells into osteoblasts (metaplasia).

This method of osteogenesis is called *direct metaplastic bone formation* or *desmal bone formation, first mode,* as the bone forms and grows chiefly by osteoblastic proliferation without participation of the fibrous or chondroid tissue. This manner of bone formation is replaced by other types of bone formation according to the time interval (about three days after operation) because biomechanical neutrality is soon lost when muscle action has recovered.

After three to four weeks, osteoclasts disappear, osteoblasts cease to proliferate,

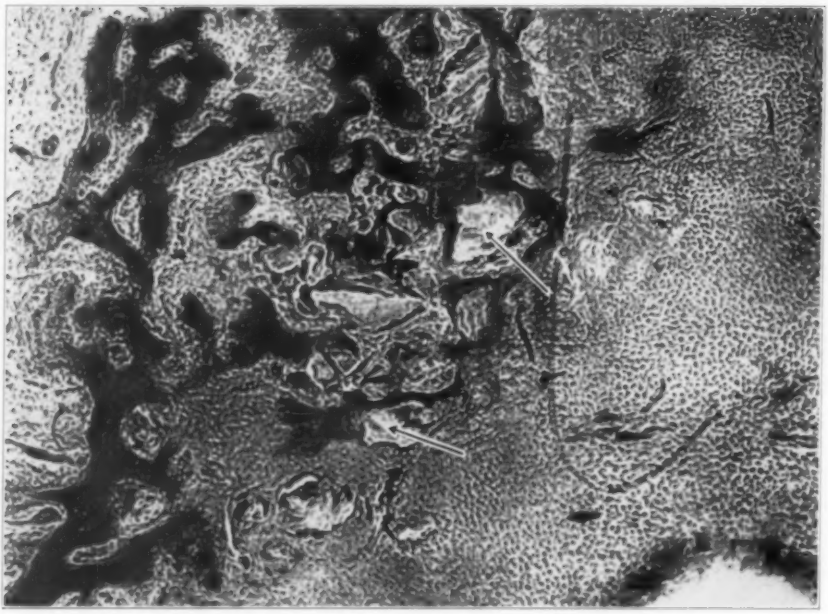

FIG. 38

Compression necrosis of newly formed bony tissue of sealing callus (bone marrow cavity). Vigorous proliferation of chondroid tissue (right) compresses the bony tissue (left), causing necrosis (arrows) (× 85).

lacunae become much narrower, and trabeculae grow thicker and more uniformly calcified, thus resembling secondary bone.

B. *Callus Differentiation under Compression*

Normally enchondral bone formation occurs at the stage of hyaline cartilage, although it is found occasionally that the chondroid tissue and the intermediate forms are transformed directly into bone by metaplastic bone formation, with individual cartilage cells being transformed into bone cells.

Under moderate compression, hyaline cartilage tends to ossify rapidly by enchondral bone formation. On the other hand, abnormally great compression, especially if it is intermittent, causes vigorous proliferation of the cartilage callus, and particularly of the callus composed of chondroid tissue. Partsch is of the opinion that the formation of cartilage callus under compression is due to circulatory disturbance rather than directly to mechanical factors, but Wehner, Biebl, and Krompecher regard mechanical factors of compressive force as most important.

In external callus formation, roentgenograms will show a mound-like elevation containing bony tissue outside, hyaline cartilage next to it, and chondroid tissue inside.

Owing to the overgrowth of the chondroid tissue, often the bony tissue, hyaline cartilage, and the surrounding soft tissues are pushed aside. Ossification is temporarily delayed on one side and an oedematous gap is produced between the soft tissue and the slope of the bony tissue on the other (Fig. 37).

When the chondroid tissue expands in the marrow, compression necrosis of the bony part of sealing (internal) callus may be noticed (Fig. 38). It is interesting that the cartilage callus can destroy the neighboring tissues and stop or delay ossification by excessive proliferation. Furthermore, various pathological changes occur within the callus itself.

These are regressive changes, such as softening necrosis. Necrotic areas of cartilage are often surrounded by, or are continuous with, cartilage which is rich in deeply staining

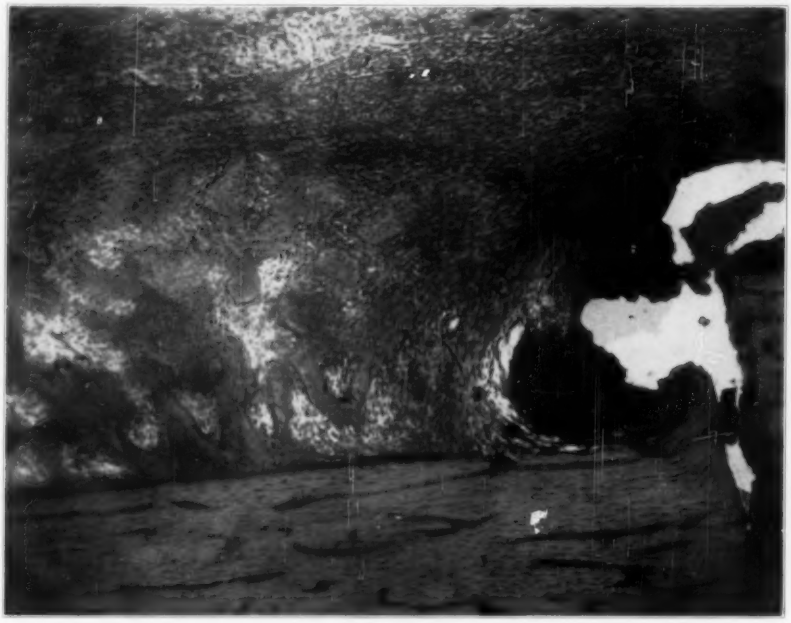

FIG. 39

Desmal bone formation, second mode (× 63).

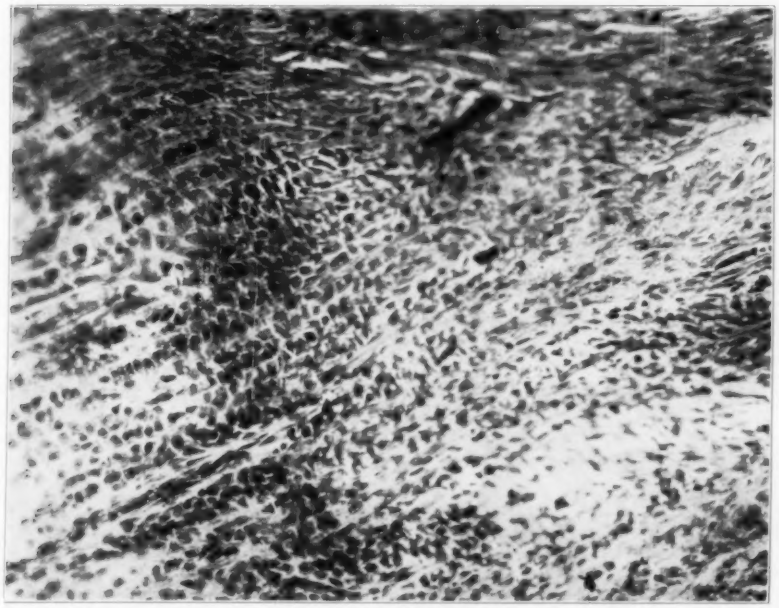

FIG. 40

Desmal-bone formation, second mode (a little later than that shown in Fig. 39) (× 188).

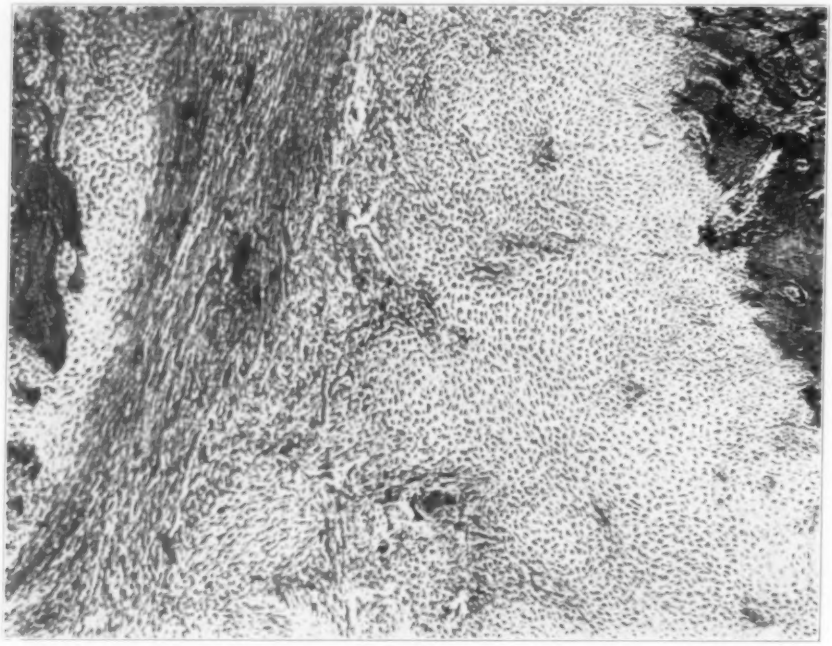

FIG. 41

Transformation of fibrous connective tissue into chondroid tissue (× 127).

FIG. 42

Enclosure of fat tissue in the fibrous connective tissue of uniting callus (× 127).

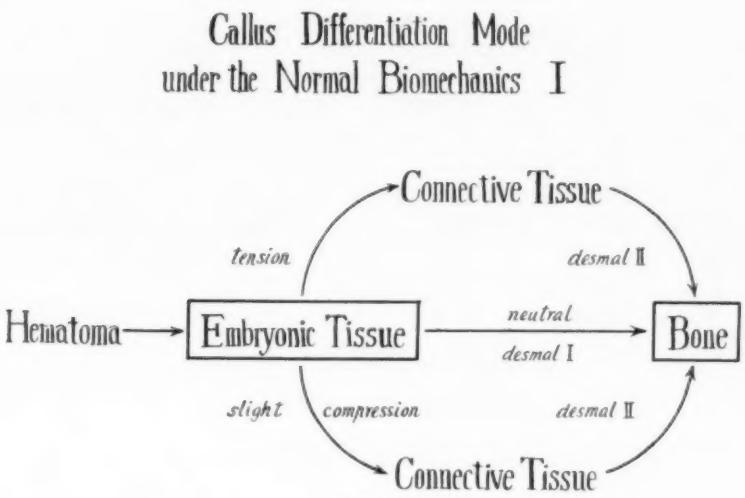

FIG. 43

cells, comparatively poor in ground substance, and thus fairly different from the usual hyaline cartilage (Figs. 20, 21, and 22).

By further investigation, it was made clear that the compressive force beyond a certain grade is necessary to allow the mesenchymal tissue to differentiate into cartilage tissue. Slight compression cannot direct the mesenchymal tissue to cartilage. Thus a greater amount of external callus chiefly composed of fibrous connective tissue, in cases in which compressive fixation was used, may also be due to a stimulating factor probably produced from the necrotic ends of bone, although chondroid tissue is seen sometimes in the bridging callus. These facts indicate that the mesenchymal tissue has an original tendency to differentiate into fibrous connective tissue.

C. *Callus Differentiation under Extension*

Under extensile fixation, the mesenchymal tissue exhibits a tendency to differentiate

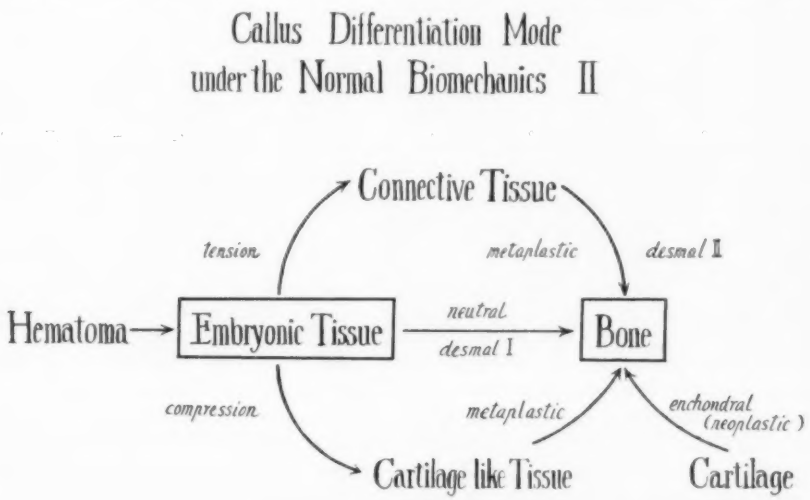

FIG. 44

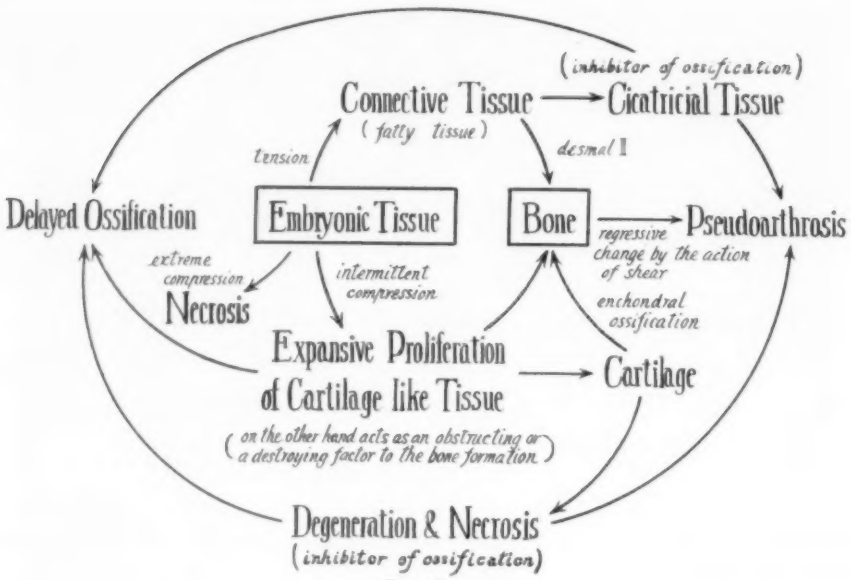

FIG. 45

Mode of callus differentiation under conditions of abnormal biomechanics.

into fibrous connective tissue, which then becomes bony tissue by intramembranous bone formation. This process is called *indirect metaplastic bone formation* or *desmal bone formation, second mode* (Figs. 39 and 40), in order to distinguish it from the type of formation under neutral biomechanics.

When the extension is great, or is gradually increased every two to three days, the fibrous callus increases markedly; part of it begins to enclose fat tissue (Fig. 42) and part of it becomes thick, resembling cicatrized fibers. Both changes are pathological and ossification is delayed. That considerable cartilage callus also appears in fractures immobilized with extensile fixation is explained by the fact that this method of fixation is unstable, and the principal biomechanical component is not well controlled. Fibrous connective tissue is the predominant constituent of the uniting callus and the sealing callus and is formed under the influence of extensile force, while the cartilage appears almost exclusively in the external callus.

In the early stage of differentiation, the cartilage callus and fibrous connective-tissue callus are reversible through extension or compression (Fig. 41). In later stages, the reconstruction or reorganization of newly formed bone in cases of compression and extension is carried out as in cases biomechanically neutral.

D. *Callus Differentiation under Shearing Force Combined with Intermittent Compression*

Pseudarthrosis was obtained as has already been noted. The fracture callus was characterized by a greater amount of cartilaginous callus and a lesser amount of fibrous-tissue callus. Some part of the former changes into bone through normal enchondral ossification, while some undergoes various regressive changes, such as myxomatous degeneration, softening, crevice formation, and pyknosis of the nuclei. The fibrous-tissue callus, also, may ossify partially, but the greater part of it becomes cicatrized and shows little tendency to further ossification. In the bony tissue, many regressive changes occur, including lacunar resorption (which is a normal reorganizing process), linear resorption, occasionally, and myxomatous degeneration, often.

Pseudarthrosis, therefore, may be defined, from the histological point of view, as a

TABLE II

CLASSIFICATION OF THE ROENTGENOGRAMS OF THE CLINICAL CASES

Fixation	Callus	Femur	Tibia and Fibula	Humerus	Radius and Ulna	Total
External nail fixation of the authors.	*F* type	4	9	1		14
	C type					
	E type					
	S type		1			1
Total		4	10	1		15
Fixation in plaster.	*F* type		3			3
	C type	2	5	1	1	9
	E type				1	1
	S type	1		1		2
Total		3	8	2	2	15
Skeletal traction.	*F* type	1	1			2
	C type	2				2
	E type	1				1
	S type	1				1
Total		5	1			6
Total		12	19	3	2	36

complex of various degenerative changes occurring in both callus and bone and resulting in delayed ossification and non-union, while, in some cases of pseudarthrosis, normal bone formation occurs simultaneously.

A schematic formula of the callus differentiation connected with biomechanical factors is outlined in Figures 43, 44, and 45.

FIG. 46

CLINICAL OBSERVATIONS

In order to make comparative clinical

FIG. 47

Fig. 46: Fracture of the tibia and the fibula treated non-operatively with the authors' apparatus. Shows bony union of type *F*. The patient was a male, aged forty. Roentgenograms were made nine weeks after injury.

Fig. 47: Fracture of the lower part of the femur, treated operatively with the authors' apparatus. Shows bony union of type *F*. The patient was a male, aged twenty-six. Roentgenograms were made ten weeks after operation.

FIG. 48

FIG. 49

Fig. 48: Fracture of the tibia, fixed in plaster, showing type *C* callus. The patient was a male aged forty-six. Roentgenograms were made seven weeks after injury.

Fig. 49: Fracture of the shaft of femur treated by skeletal traction. The patient was a male, aged forty-three. Repeated reductions were attempted. Roentgenograms were made fourteen weeks after injury and shows delayed union with type *S* callus.

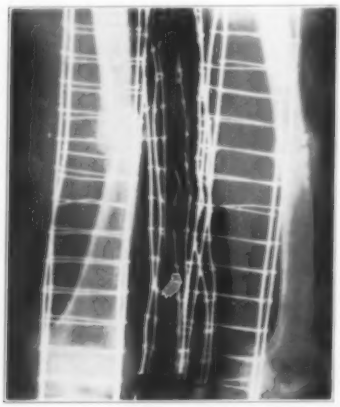

FIG. 50

Fig. 50: Fracture of the shaft of the femur. The patient was a male, aged twenty-eight. After open reduction, traction was applied for seventeen days and was replaced by plaster fixation. Thirteen weeks after operation, the fracture still showed evidence of abnormal mobility. The roentgenogram made at that time reveals delayed union in spite of a great amount of callus formation (type *E*).

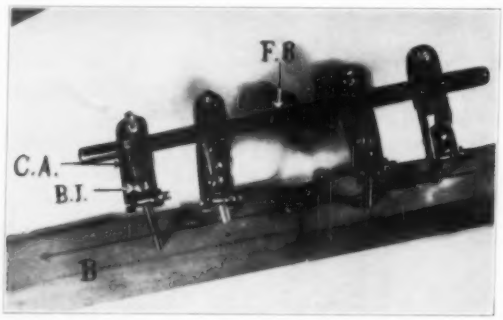

FIG. 51

Fig. 51: The authors' external nail-fixation apparatus. This is made of 18–8 stainless steel. Nails inserted into the bone (*B*) are held between two hemispheres which are held between the jaws of the connection apparatus (*C.A.*), making a ball-joint (*B.J.*). The whole connection apparatus is held with a fixation bar (*F.B.*). Note the position and the direction of each nail, which can be put into the bone at any desired angle within certain limitations.

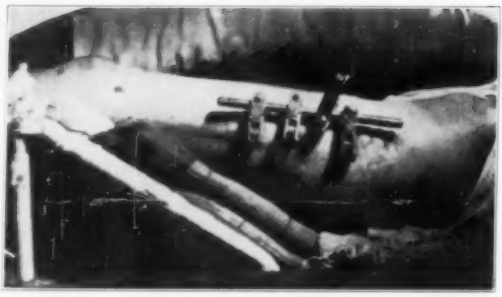

FIG. 52

Picture of apparatus used in treatment of fracture of the femur.

observations of fracture healing, influenced by biomechanics, sixty-seven cases of fractures of the shafts of long bones were selected and observed by M. Kono, one of our asso-

ciates, at the International Good Will Hospital in Yokohama. Thirty-six cases of transverse fracture or oblique fracture of slight degree (30-degree maximum) were selected; infected compound fractures, spiral fractures, or comminuted fractures were excluded.

These cases were classified according to method of fixation and the kind of bone formation, and were studied roentgenographically. The methods of fixation which were used in this study are (1) external nail fixation devised by one of us [19], (2) fixation in plaster, and (3) skeletal traction.

These cases, the type of fixation, and the roentgenographic data are recorded in Table II.

As seen in this table, all fractures treated by external nail fixation healed with callus formation similar to type *F* observed in the animals, except one tibial fracture which resulted in delayed union showing callus of type *S*. The fixation achieved by this apparatus is so firm that the fractures treated by this method are thought to be similar to the experimental fractures treated by firm controlled fixation. In addition, it is convenient for non-operative treatment, because the direction and the position of each nail inserted into the bone can be varied within a wide range by the connection apparatus, which has a ball-joint between each nail and the fixation bar. It may be suggested that the small amount of callus formation in these cases may be the result of operative reduction. However, five fractures, non-operatively fixed by this apparatus, showed callus identical in type with the operative cases. Thus it is our opinion that the callus type in these fractures is chiefly dependent on the mode of fixation and is not a result of operative reduction.

In fifteen fractures fixed with plaster casts, nine healed with callus of type *C* and three with callus of type *F*, but the remaining fractures showed callus of type *E* or *S*. The cause is apparent when one considers that this method, with early active use of the extremity, is almost identical with the loose controlled fixation or compressive fixation. On the other hand, it is expected that the callus formation of a fracture such as a fracture of the femur or of the bones of the upper extremity, where an abundant mass of muscle tissue surrounds the fracture, will sometimes show callus of type *E* or *S* because the mere fixation in plaster at such a site may be mobile and various biomechanical factors may arise in the fracture site.

The fractures immobilized in skeletal traction showed every type of callus formation, but our cases are too few for an evaluation of the results. It is quite possible that callus formation of type *E* or *S* may occur if too much traction has been applied or if it is repeated carelessly. The fractures shown in Figures 49 and 50 are good examples of treatment by inadequate traction, resulting in delayed union.

From these clinical findings, it appears that callus formation in man is not only closely related to the method of fixation but is also governed by the same biomechanical factors as in animals. If this view is correct, one should be able not only to determine the principal biomechanical factors but also to predict the histological findings in each callus type.

We have examined a few specimens of human fractures showing normal healing and we have found essentially no difference between that in human patients and that in animals.

For optimal healing, a moderate, intermittent compression of the organizing tissue at the fracture surface by muscle contraction is necessary. Excessive compression may cause tissue necrosis, while too much traction may lead to delayed union. It must be kept in mind that diastasis may delay the healing extremely when excessive intermittent compression is added.

There are many methods of fixation, each with its own merits. The selection of the method of fixation should be determined by the individual situation. The plaster cast is one of the best methods because it not only is simple to use but also can produce favorable biomechanical conditions. The excellent results from the use of the intramedullary nail

have recently been recognized, in spite of the disadvantage of having a foreign body in the marrow. It is obvious that the strong point of this method is in the environment, which brings out the best biomechanical factors. One of us has recently developed an improved external nailing apparatus, the fixation bar of which is improved so that half of it can slide as a sheath in itself along the longitudinal axis, producing moderate intermittent compression.

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REPAIR OF HERNIAE THROUGH ILIAC-CREST DEFECTS *

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It is not generally recognized that herniae may occur through defects in the iliac crest following removal of bone for use in bone-grafting. Such herniations are rare; but when they do occur they are extremely disabling. We have encountered three such cases during the past ten years. In all of the three cases, herniations of abdominal contents had occurred through defects in the mid-portion of the crest. We have never seen such herniation occurring when the crest had been removed in the anterior portion as well as in the mid-portion. Apparently it is essential that a rigid ring defect be present to provide a mechanical situation in which repeated sudden compressive changes within the abdomen (as on coughing) act continuously and, eventually, disrupt the supporting soft tissues to produce a herniation. In the first patient, the defect was so extensive and the herniation was so great, that it was felt, at first, that repair would be impossible. Because of the complete disability of the patient, however, the problem was studied for some time and, eventually, the method of repair to be described was devised and finally it was successfully employed.

The first patient was operated upon in October 1945. She had had pyogenic osteomyelitis of the right ilium in 1940. Extensive resection of the mid-portion of the crest and body of the ilium had been done in 1942 (Fig. 1-A). Herniation through the defect gradually occurred and during the two years preceding our attempted repair she had been totally bed-ridden because of pain and progressive enlargement of the herniated mass. With considerable misgiving, plastic repair at the site of the hernia was done. Following repair, complete bed rest was continued for three months. She was then allowed up with crutches and within two months she was free of the crutches and had returned to her occupation as a secretary. She has remained

FIG. 1-A

Roentgenogram showing defect in iliac crest preoperatively.

* Read at the Annual Meeting of the Section on Orthopaedic Surgery, Medical Society of the State of New York, Buffalo, New York, May 11, 1955.

FIG. 1-B

Pelvis following obliteration of iliac defect resulting in repair of the hernia.

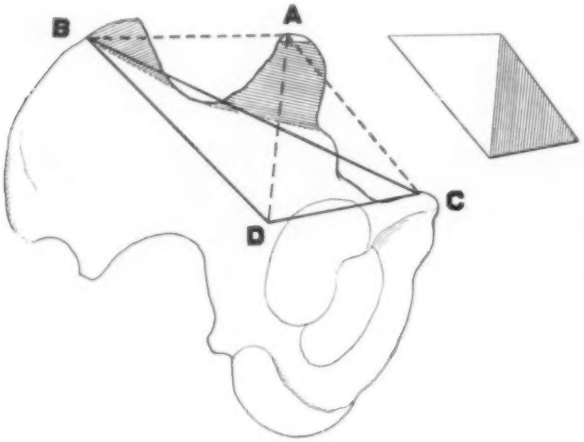

FIG. 2

The structures involved in the proposed repair represent a pyramid.

asymptomatic, with no further evidence of hernia, and on full activities up to the present time, ten years after operation. Deformation (Fig. 1-B) and scarring are appreciable with the patient stripped of clothing; clothed, the deformity is not apparent.

In the second patient, a considerable amount of bone had been removed from the mid-portion of the iliac crest and from the body of the ilium for use in an attempted spine fusion for spondylolisthesis. We first saw her one year later. The fusion was the seat of a pseudarthrosis and this was first repaired. Thereafter, because of continuing disability due to a hernia through the iliac crest, the hernia was repaired by the procedure to be recorded. Two months later, she had returned to her work as an industrial nurse, was asymptomatic and clinically normal except for moderate scarring and mild appreciable defects in outline of the pelvis. When clothed she appeared and acted normally. The case has been followed up to the present time, a period of eight years. The spine fusion was solid and there was no recurrence of herniation and no symptoms.

The third patient had sustained a fracture of the jaw in 1936. A large segment of the mid-portion of the left iliac crest and a moderate portion of the body of the ilium had been removed to repair the defect in the jaw. Symptoms from herniation through the iliac defect gradually became appreciable by 1946. He was totally disabled by 1950 with severe pain, but had only a moderate-sized hernia. In March 1950 obliteration of the hernial opening through the iliac crest was successfully accomplished. Six months later he had returned to his regular work as a farmer. This case has been followed up to the present time, a period of five years.

THEORY OF REPAIR

At first, believing that repair of the considerable defect in the iliac crest in the original patient was impossible, we saw no way of repairing the hernia. Later, we realized that in our own patients when we had used the ilium for donor grafts and the anterior portion of the crest had been removed, no herniae had occurred. On further study, we found by measurements, made on the roentgenogram, that transplantation of the anterior superior iliac spine distally on the outer surface of the ilium and beneath the periosteum and gluteal muscles would not greatly increase the distance from the posterior margin of the defect

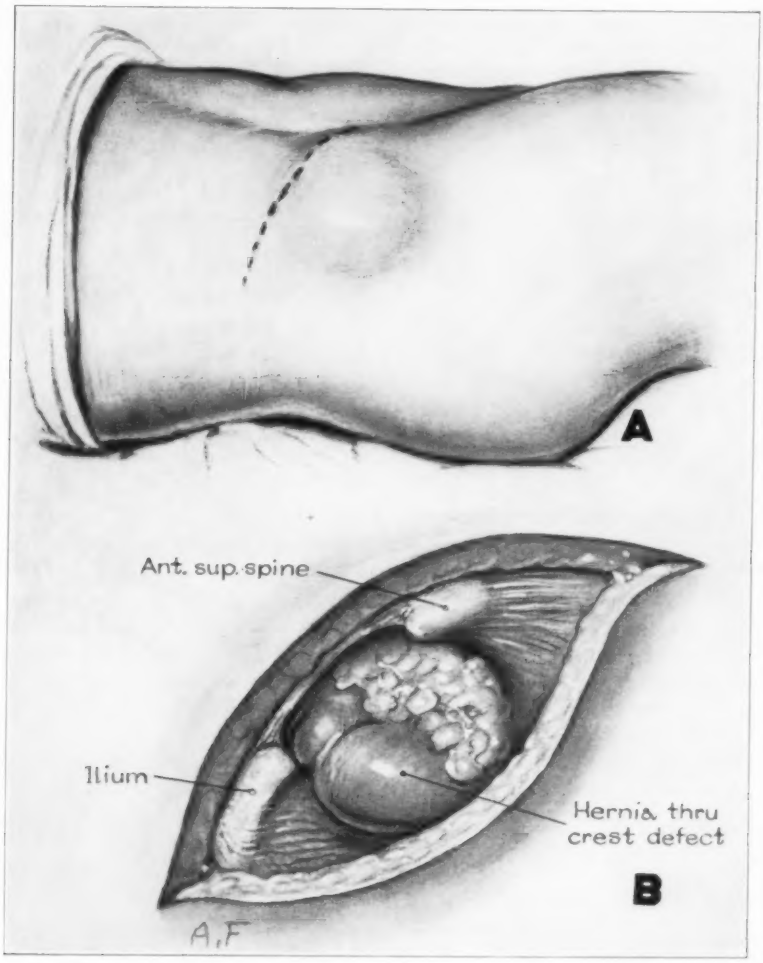

FIG. 3

A: Appearance of herniation through defect in the mid-portion of the iliac crest.
B: Dissection showing the herniation.

to the transposed spine or from the spine to the pubis (Poupart's ligament) provided that the ilium below the anterior superior spine was removed. Furthermore, the musculature of the abdominal wall would not have to be stretched too greatly since, with the outward-flaring ilium removed, the abdominal-wall muscles could be brought practically straight downwards.

Actually, in visualizing the structures before repair one notes that they are seen to represent a pyramid (Fig. 2) with the apex at the anterior superior spine (*A*). One base line extends from the posterior margin of the proposed excision of the ilium behind the hernia (*B*) forward to the pubic bone (*C*). A second base line extends downward from the pubic bone to the lower limit of mobilization of thigh muscles,—that is, the tensor fasciae latae and the sartorius (*D*). The third base line extends from *D* back to *B*.

Transplantation of the anterior superior spine (*A*) distally and posteriorly, after

FIG. 5

FIG. 7

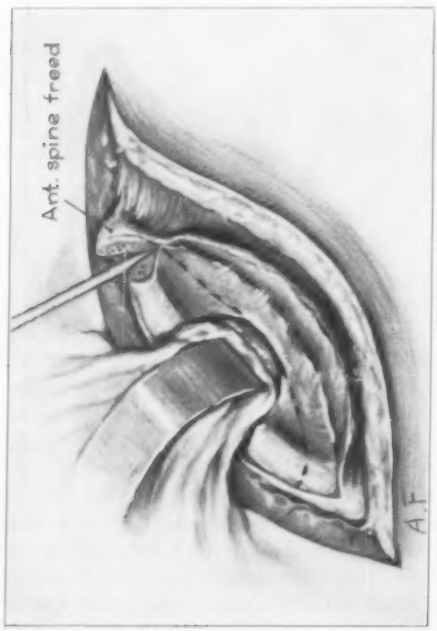

FIG. 4

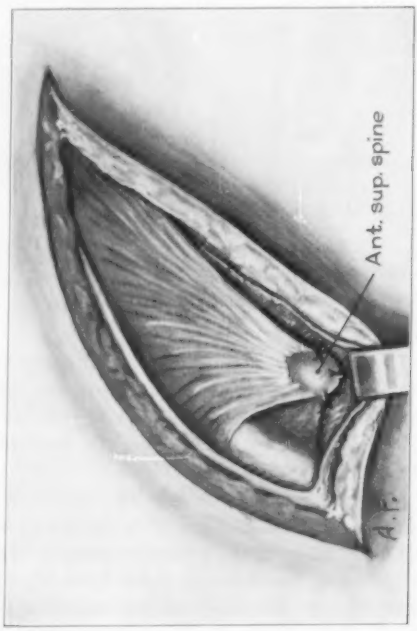

FIG. 6

Fig. 4: This shows replacement of the hernia. Note that the anterior superior iliac spine is being freed. The dotted outline shows the amount of ilium that will be removed and discarded.

Fig. 5: This shows the hernia replaced, the ilium resected in part, anteriorly and posteriorly, and its free border made straight. In this way, the hole in the body of the ilium has been removed. The anterior superior iliac spine with attached structures is being mobilized.

Fig. 6: Transplantation of the anterior iliac spine and its attached structures beneath the periosteum and gluteal muscles distally and backward on the outer surface of the ilium is shown. It is attached there by interrupted sutures.

Fig. 7: Suture of the fascia of the thigh to that of the abdominal wall, across the transplanted anterior superior spine and its attached soft tissues, has been done, thus reinforcing the area.

straightening the iliac crest by resection of the bone above the dotted lines, draws the muscular, fascial, and ligamentous structures the margins of which are represented by the lines *BAC* tightly across the defect in the abdominal wall. By this procedure the apex of the pyramid is placed below the plane of the base *BCD* and the pyramid is thus inverted. Stretching of the structures in the triangle *ADC* and along the lines *BAC* is greatly reduced by the removal of the iliac crest represented by the shaded area anterior and posterior to the crest defect.

Some stretching of the periosteum of the iliac crest, of Poupart's ligament, and of the abdominal muscles was found necessary. Such stretching of these structures across the revised crest proved of benefit in promoting reattachment and preventing reherniation.

OPERATION

The operation (Figs. 3, 4, 5, 6, and 7) consists of an incision along the anterior two-thirds of the former site of the iliac crest exposing the anterior superior spine, the fibrous raphe of the margin of the abdominal musculature above the hernia and the crest of the ilium which lies posterior to the hernial defect. The hernial mass is dissected and replaced in the abdomen. The posterior part of the iliac crest forming the posterior margin of the defect is leveled. The anterior superior iliac spine with its attachments is removed and the ilium below it is then removed subperiosteally in line with the lower border of the defect through which the hernia came. This in effect removes the defect in the ilium and leaves a new iliac crest which is straight. The anterior superior spine is then drawn downward, the fascial, muscular, and ligamentous attachments being mobilized by blunt dissection. The transposed spine is fastened beneath the periosteum on the outer surface of the ilium deep to the gluteal muscles with two or three double chromic catgut sutures. The gluteal raphe and fascia of the thigh are brought up and sutured to the fascia of the abdomen, crossing and reinforcing the repair. The skin and fat are closed.

Following this repair, it was found that the muscular and ligamentous attachments to the anterior superior spine are drawn tightly across the new crest of the ilium where they reattach.

CONCLUSIONS

1. Herniations through defects in the mid-portion of the iliac crest may occur and may be extremely disabling.

2. Removal of bone from the iliac crest for grafting purposes should always include the complete crest from the anterior superior spine region backward and should not leave an opening in the mid-portion of the crest.

3. Repair of such herniations, even when quite extensive, has been successfully accomplished in three cases by the procedure given.

PATELLAR PROSTHESIS *

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Repeated trial of patellectomy and various patellar plastic operations and subsequent observation of these cases over a period of years has left many surgeons dissatisfied. In fractures and chondromalacia, with no other internal derangement, patellectomy will undoubtedly produce good results after prolonged physiotherapy, but these are simple problems compared with arthroplasty or the débridement and reconstruction procedures necessary in knee joints badly damaged by trauma, degenerative changes, or disease. In such cases, patellectomy frequently imposes an insurmountable obstacle that leads to failure, when restoration of the extensor mechanism to normal, or nearly normal, would have produced a good result.

Cosmetically, patellectomy leaves much to be desired, particularly in women.

Without a patella, the femoral condyles have no protection from direct trauma in falls and when kneeling. A knee without a patella may be better than one in which the patella has a roughened or misshapen articular surface, but it cannot function as well as a knee with a good patella. It seems logical to conclude that, while patellectomy produces some satisfactory results in the simpler problems involving the extensor mechanism, it is not a satisfactory procedure in more complicated knee-joint problems, and, in any case, it must be possible to do better.

FIG. 1-A

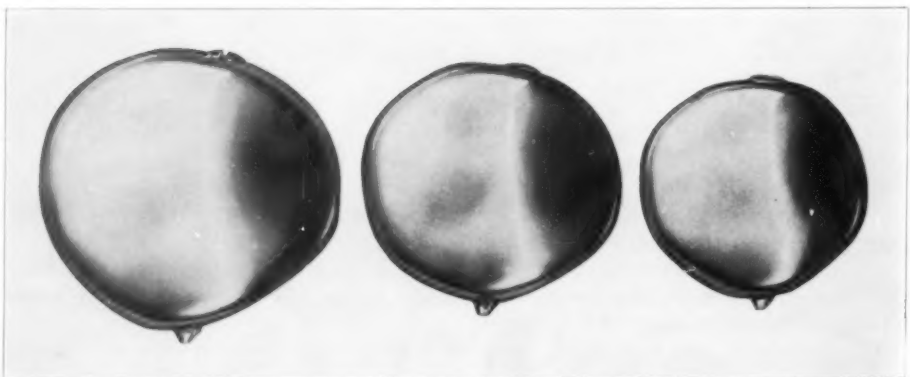

FIG. 1-B

* Based on a motion picture shown as part of the Audio-Visual Program of the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 23, 1954.

A prosthesis for the articular surface would permit the retention of the patella. A knee joint, normal in mechanics, appearance, and function, should be possible in those patients in whom only the patella is at fault. A much better knee joint should be obtainable in knees having both a defective patella and other mechanical defects, and it is in these cases that the use of a prosthesis could contribute greatly to a good result.

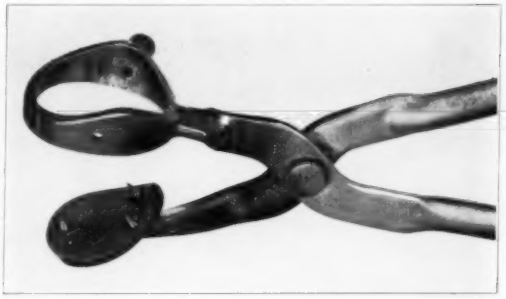

FIG. 2

With a normal patella as a model, a Vitallium prosthesis was designed so that the osseous portion of the patella could be fitted into it (Fig. 1-A). A screw transfixing the patella and both lips of the prosthesis hold it in place when the quadriceps is relaxed. When the quadriceps is under tension, the screw is probably non-functional.

This prosthesis has been produced in three sizes (Fig. 1-B). The largest is used in the majority of cases. The medium size, made at the instigation of Dr. Garrett Pipkin, is 12.5 per cent. smaller. It is used in small individuals and, in case of question, this size is preferable. The smallest size might be used in children, but to date this has not been tried.

A jig was devised later in order to facilitate fitting the patella to the prosthesis. This instrument may save thirty minutes or more in operative time, but the prosthesis can be fitted without it (Fig. 2).

TECHNIQUE OF APPLICATION

A median parapatellar incision is recommended because it facilitates orientation in placement of the prosthesis. It is not necessary to disturb the insertion of the patellar tendon. The initial incision is carried directly into the joint. The skin is reflected laterally so as to expose the anterior surface of the tendon overlying the patella. The patella can then be turned over, completely exposing its articular surface. Necessary débridement or reconstructive work on the remaining portion of the joint is carried out first.

In all cases, the patella should be trimmed to fit the prosthesis. If, by chance, the patella will fit the large-size prosthesis without alteration, this size should still not be used because the resulting articular surface of the prosthesis would be larger than that of the original patella and would not fit the condyles.

In every case some portion of the patella will have to be trimmed away. The distal and medial portion should be preserved. The jig is to be placed in such a position that this portion is under the plate which determines the circumference. The portion to be removed is the superior and lateral portion. A motor saw, rongeur, or any other cutting instrument the surgeon may prefer can be used.

The jig is applied with the points on the plate side, sticking into the articular surface of the patella and the ring on the anterior surface of the patella (Fig. 3). *If the points will not engage, a preliminary cut may be made to convert the articular surface to a flat plane.* The jig will be almost at right angles to the axis of the leg, but should be placed without particular regard to this position. In placing the jig accurately in alignment, the axis of the two most prominent parts of the edge of the ring, which will be in line with the vertical ridge on the prosthesis, should be in the axis of the intercondylar groove. This is the guide for the application of the jig. The drill guide position is also disregarded, as it purposely does not coincide with the vertical axis of the patella. It was so placed to prevent loosening of the screw by the torque exerted on the patella as the knee flexes and extends.

The jig is removed, turned over, and re-applied in the same axis of the intercondylar

FIG. 3

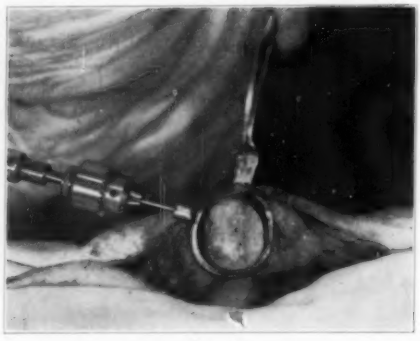

FIG. 4

FIG. 5

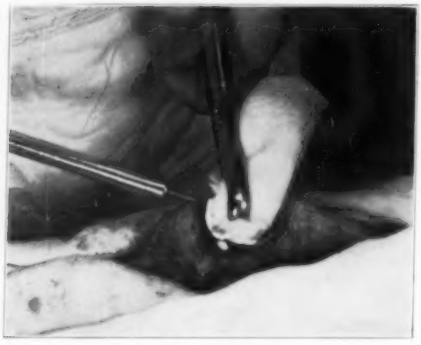

FIG. 6

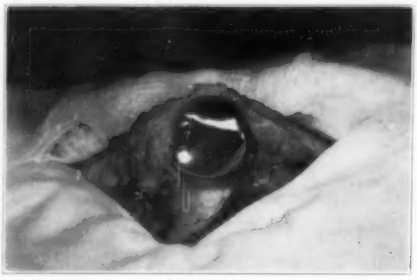

FIG. 7

groove, as determined above, and closed tightly. A seven sixty-fourths of an inch drill is passed through the drill guide and the patella, and the chuck is removed leaving the drill in place (Fig. 4). That portion of the patella protruding through the ring is cut off flush with the ring (Fig. 5). The remnant will be thinner than the original patella and should just fill the prosthesis. In young vigorous individuals the patella is very hard and is cut with difficulty. In older and less active individuals, it is relatively soft and easy to cut. The drill and jig are removed.

The prosthesis is placed on the reshaped portion of the patella so that the small facet is toward the edge of the incision. The prosthesis is clamped tightly on the patella and is held with a lion-jaw forceps in such a position that the screw holes in the patella are in line with the screw holes in the prosthesis. This is made easier by passing a probe or pin through the prosthesis and the hole in the patella before the clamp is applied. An accurate fit is not essential, but the patella should be seated into the prosthesis as deeply as possible. The screw is then inserted tightly, so that the tip of the screw engages the threaded screw hole in the prosthesis (Fig. 6). Only one of the screw holes is threaded. It may be at the top or the bottom depending on which side is being fitted. If the prosthesis has been applied properly, it will turn over into functional position so that the smaller facet faces the medial condyle and the larger facet faces the lateral condyle (Fig. 7).

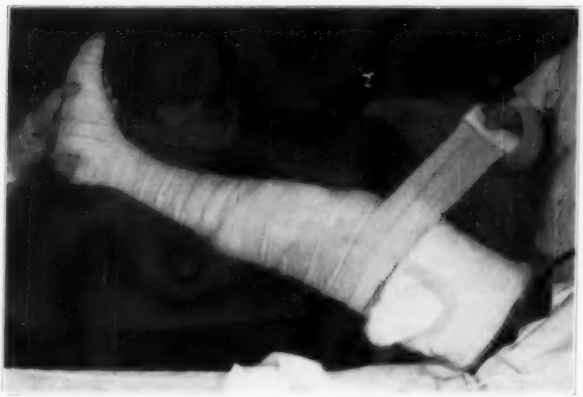

FIG. 8

Especial care should be taken to see that there is no ridge at the proximal edge of the intercondylar groove so that the prosthesis may pass over this area without catching or interference. If such a ridge is present, it should be removed with an osteotome or a motor burr.

Effusion, as a postoperative complication, can be minimized by making an opening from the suprapatellar pouch into the space beneath the quadriceps muscle, as recommended by Chandler [1]. This procedure is recommended. The incision is closed. These directions may be followed for either knee, as the prosthesis and the jig may be used on either side by merely rotating them 180 degrees.

Postoperatively a cotton and elastic pressure bandage is applied to the knee (Fig. 8). This is removed at the end of forty-eight hours and motion is started at once. Weight-bearing can be started as soon as the patient is able to raise the extended leg against gravity. When only the patella is damaged, 90 degrees of motion should be easily obtainable within three weeks. When there is extensive involvement of the remaining portion of the knee joint, the restoration of motion and the return of function will depend on the degree of damage and the determination of the patient. If a postoperative effusion occurs, it should be removed by tapping. Hyaluronidase may be used to assist the absorption of the effusion. Hydrocortisone may be used intra-articularly if the surgeon wishes.

The following cases are representative. One fresh fracture is included. In all of the other cases, there was extensive damage to the remainder of the knee joint and in all of them both menisci were removed, articular margins were trimmed, and partial synovectomies were performed. In spite of this the patients have little, if any, disability.

CASE 1. A female, aged sixty, in whom the diagnosis was bilateral chondromalacia of the patella and degenerative arthritis, had had gradually increasing disability of both knees of one year's duration, recurrent giving-away and locking in the right knee, and chronic swelling in the right knee for three months.

Examination revealed that the patient stood and walked with both knees slightly flexed. They could be passively extended. There was crepitus on active and passive motion of the patella. There was a small amount of effusion in the right knee. She was unable to go up and down steps without assistance. There was evidence of injury to the menisci of the right knee.

On May 19, 1949, bilateral arthrotomy was carried out. In the right knee the medial meniscus was found to be displaced, and the lateral meniscus was badly frayed near its anterior attachment. They were excised. The lower two-thirds of the patella was completely devoid of cartilage. The edges of the patella were trimmed and a patellar prosthesis was applied.

A similar procedure was carried out on the left knee. The patella showed an almost complete loss of cartilage surface. There was beginning fraying of the medial meniscus and complete dislocation of the lateral meniscus into the intercondylar groove where it was eroding the cartilage of the lateral condyle. Both menisci were excised. The patella was partially resected to fit the prosthesis and the incision was closed.

Physiotherapy was started on the fifth day. Weight-bearing was started on the twelfth day. At three weeks, there was 50 degrees of flexion in the left knee and 30 degrees of flexion in the right knee. At three months, there was more than 90 degrees of flexion in each knee. The patient was able to walk with a normal gait and to go up and down steps. The patient has continued to be normally active. When she walks both knees go into complete extension at the onset of weight-bearing; she can step up and down an eighteen-inch step with either leg without assistance. There is no effusion and no swelling. There is very fine crepitus beneath the patella on active motion. The patient is not aware of any disability whatever, and five years and six months after operation she stated, "I have almost forgotten my knee operations".

TABLE I

Case No.	Age	Sex	Diagnoses in Addition to Chondromalacia of the Patella	Motion or Deformity	Date of Surgery	Procedures Done in Addition to Patella Prosthesis
1	42	F	Rheumatoid arthritis	Limited flexion and extension	3- 3-49	Complete synovectomy, excision of menisci, and débridement
2	26	M	Malunion of fracture, lower end of femur; ankylosis of patella	Flexion contracture	3-10-49	Débridement
3	60	F	Internal derangement on the left	Limited voluntary extension	5-19-49	Excision of menisci
			Internal derangement on the right	Limited voluntary extension	5-19-49	Excision of menisci
4	70	M	Fractured tibial plateau and gouty arthritis	Fracture deformity and flexion contracture	3-23-50	Repair of medial plateau, excision of medial meniscus, and synovectomy
5	55	M	Degenerative arthritis and internal derangement on the left	Limited flexion and extension	6-15-50	Excision of menisci and débridement with partial synovectomy
			Internal derangement and degenerative arthritis on the right	Locked in flexion with lateral meniscus	7-28-54	Excision of menisci and débridement with partial synovectomy
6	46	F	Displaced medial meniscus	Slight limited flexion and extension	8-21-50	Excision of medial meniscus
7	72	F	Degenerative arthritis	Slight flexion contracture	9-11-50	Excision of menisci and débridement
8	57	F	Rheumatoid arthritis	Limited flexion and extension	9-21-50	Synovectomy and excision of menisci
9	37	M	Internal derangement	Limited extension	1- 4-51	Débridement and excision of menisci
10	56	F		Slight flexion contracture	4- 9-51	Partial synovectomy
11	44	F	Rheumatoid arthritis	Slight flexion contracture	7- 2-51	Synovectomy; débridement; nylon interposition
12	50	F	Degenerative arthritis and traumatic arthritis	Unstable—22° of valgus	8- 6-51	Excision of menisci; tibial plateau elevated with bone graft
13	57	F	Fractured patella	Fracture deformity	10-25-51	None
14	48	M	Internal derangement; gout	Torsion bowing of the tibia	1-10-52	Plateau elevation with bone graft; excision of medial meniscus; nylon interposition
15	44	F	Internal derangement; plica synovialis	Slight flexion contracture	3-13-52	Partial synovectomy and débridement
16	57	F	Monarticular and degenerative arthritis; synovitis	Limited flexion and extension—on crutches for one year	5- 5-52	Complete synovectomy; débridement; excision of menisci; bilateral plateau prostheses
17	32	F	Internal derangement of menisci; early traumatic arthritis	None	6-30-52	Excision of menisci
18	66	F	Degenerative arthritis	None	10-16-52	Partial synovectomy and débridement
19	36	M	Old osteomyelitis	Almost complete ankylosis	11- 3-52	Removal lower femoral condyles; bilateral plateau prostheses; nylon interposition; débridement

TABLE I

Days in Hospital; After Operation	Ambulatory on Dismissal	Physio-Therapy Treatments	Last Check-up Date	Remarks and Final Estimate
30	No	4	5–18–49	Postoperative infection; prosthesis removed; ankylosis
30	Yes	About 20	1–16–53	Flexion could be improved by further surgery but patient is satisfied and fully active
21	Yes	7	7–20–54	Normal activity; flexion and extension complete
21	Yes	7	7–20–54	Normal activity; flexion and extension complete
6	No	24	3–23–54	Cast applied for six weeks postoperative; flexion and extension complete; normal activity
9	Yes	4	3–17–55	Flexion and extension complete; works daily as peddler on horse-drawn vegetable cart
7	Yes	None	3–17–55	Flexion and extension complete
9	Yes	21	10–27–54	Normal activity; flexion and extension complete
13	Yes	38	12– 1–53	Normal activity; will not flex beyond 110°; prosthesis too large
13	Yes	68	8–13–54	Has an ankylosis of other knee; has a hip prosthesis; final flexion 80°
12	Yes	9	10–14–54	Normal activity; flexion and extension complete
10	Yes	7	3– 8–55	Normal activity; flexion and extension complete
18	Yes	77	6–13–52	Ambulatory, but has severe involvement of other joints; almost complete flexion and extension
7	No	10	9–11–53	Final range of motion 45° of flexion; ambulatory; does own work
4	Yes	2	4– 3–55	Flexion and extension complete; knee normal; returned to work in 3 weeks
14	No	None	2– 6–52	Postoperative infection; prosthesis later removed and knee arthrodesed
5	Yes	8	9– 9–52	Flexion and extension complete; works as a janitress
26	Yes with crutches	23	7–29–53	Has stopped all medical treatment; has complete extension in weight-bearing; walks well
13	Yes	41	5–25–54	Convalescence slow and flexion is limited; prosthesis used was too large
11	Yes	19	3–25–55	Flexion and extension complete; normal activity except for other illnesses
11	Yes	6	3– 8–55	Postoperative infection; has had prostheses removed and knee arthrodesed

TABLE I *(continued)*

Case No.	Age	Sex	Diagnoses in Addition to Chondromalacia of the Patella	Motion or Deformity	Date of Surgery	Procedures Done in Addition to Patella Prosthesis
20	62	F	Internal derangement	None	11- 6-52	Removal loose osteophyte and excision of lateral meniscus; débridement; partial synovectomy
21	54	F	Degenerative arthritis	10° flexion contracture	2- 9-53	Partial synovectomy; excision of menisci
22	48	M	Internal derangement	Limited extension	4- 9-53	Débridement and removal of loose bodies; excision plica synovialis
23	66	F	Osteochondromatosis	Flexion contracture	5-14-53	Removal of osteophytes and removal of menisci; débridement; nylon above patella
24	36	M	Internal derangement	15° flexion contracture	6-25-53	Excision of menisci
25	36	F	Depression fracture plateau; internal derangement	Pain on motion; weakness and instability	8- 6-53	Plateau prosthesis; tibial tubercle transplant
26	79	F	Menisci badly damaged; degenerative arthritis	Slight flexion contracture; instability	9-10-53	Excision of menisci; débridement; medial plateau prosthesis
27	59	F	Rheumatic arthritis; internal derangement; synovitis	Flexion contracture; instability	11- 2-53	Excision of lateral meniscus; synovectomy; débridement
28	25	M	Osteochondritis dessicans and internal derangement	Extension limited	11- 9-53	Partial synovectomy; excision of menisci; débridement
29	76	M	Degenerative arthritis	Flexion contracture; varus deformity	3-15-54	Excision of menisci; medial plateau prosthesis; débridement
30	41	M	Fractured patella; poliomyelitis	Has old poliomyelitis	5- 1-54	Excision of menisci
31	50	F	Advanced degenerative arthritis	Flexion contracture	5-20-54	Excision menisci; partial synovectomy; débridement; medial plateau prosthesis
32	57	M	Degenerative arthritis and internal derangement	Flexion contracture	5-24-54	Excision of menisci; partial synovectomy
33	38	F	Internal derangement		7-12-54	Partial synovectomy
34	59	M	Internal derangement	Limited flexion and extension	8- 2-54	Excision of medial meniscus
35	69	F	Internal derangement and displaced menisci	Flexion contracture	9-27-54	Excision of menisci and removal of loose bodies
36	56	M	Internal derangement; acute traumatic arthritis; synovitis	Almost no motion	10-25-54	Partial synovectomy and débridement
37	38	F		Full range of motion with pain Full range of motion with pain	11- 4-54 2-28-55	
38	34	F	Rheumatic arthritis; osteoporosis due to cortisone	30° valgus deformity	2-14-55	Partial synovectomy; excision of menisci; lateral plateau prosthesis with prop-up graft
39	68	F	Chronic dislocated patella; traumatic arthritis	Limited extension; 25° valgus	2-21-55	Tibial tubercle transplant; excision of menisci; débridement; plateau prosthesis

TABLE I *(continued)*

Days in Hospital; After Operation	Ambulatory on Dismissal	Physio-Therapy Treatments	Last Check-up Date	Remarks and Final Estimate
8	Yes	10	3-22-55	Flexion and extension complete; normal activity
13	Yes	20	12- 7-54	Flexion and extension complete; still has degenerative arthritis in all joints
17	Yes	44	4- 2-55	Flexion and extension complete
12	Yes	32	4-13-54	Flexion 110°; extension complete; normal activity
7	Yes	19	2- 5-54	Postoperative infection delayed convalescence; flexion and extension almost complete; slight pain
18	No	12	2-16-55	75° flexion; extension complete; normal activity
8	Yes	53	9-21-54	80° flexion; walks well in slight flexion; normally active for age
18	Yes	24	10- 1-54	Range of motion 90° to 180°; walks well; has a hip prosthesis; débridement of other knee
11	Yes	20	3-18-55	Flexion and extension complete; normal activity; cannot run
13	Yes	16	9-22-54	Flexion and extension complete; normally active
3	Yes	None	4-11-55	Extensive paralysis from old poliomyelitis; walks with cane; motion limited by muscle transplant
28	Yes	68	3- 1-55	Patella sequestrated; patella and prosthesis removed—plateau prosthesis still in; motion complete
11	Yes	28	10-14-54	Flexion and extension complete; normal activity
9	Yes	27	1- 6-55	Flexion and extension complete; no symptoms; normal activity
8	Yes	10	2-16-55	Flexion and extension complete; no pain; normal activity
12	Yes	27	1-25-55	80° flexion; extension complete; no pain or instability
10	Yes	77	3-15-55	Flexion 80°; extension complete; walks well
7	Yes	4	5-10-55	Normal range of motion; normal activity; no pain
7	Yes	None	5-10-55	Normal range of motion; normal activity; no pain
40	Yes	35	4-11-55	Cast applied postoperatively due to prop-up graft; motion 100° to 170°; ambulatory with crutches
18	No	13	3-11-55	Fell 2 weeks postoperative while walking and fractured tibia 2 inches below knee joint; cast applied. Walking. Range of motion not known

CASE 2. A male, aged thirty-six, in whom the diagnosis was traumatic arthritis, had a history of two previous injuries to the knee joint, one approximately fifteen years and one six years before examination. The knee was swollen and disabled for several weeks after the last injury. When seen in 1950, he had been having gradually increasing disability in the knee for one year with recurrent swelling and instability.

Examination revealed marked crepitus beneath the patella during passive and active motion, definite effusion in the joint, and incomplete voluntary or passive extension. Arthrotomy was recommended.

Arthrotomy was performed on January 4, 1951. The medial meniscus was found to be displaced into the intercondylar notch where it had caused marked erosion of the medial condyle of the femur. The meniscus was excised, and the eroded area of cartilage on the femoral condyle was smoothed by trimming with a knife. The lateral meniscus was found to be displaced and to have cut a groove in the lateral condyle. It was also excised. A large portion of thickened fat pad was excised. An extensive area of chondromalacia of the patella was present with a corresponding area of chondromalacia on the opposing surface of the femoral condyle. The patella was trimmed; the cartilage surface of the intercondylar notch was smoothed by trimming it with a knife. A patellar prosthesis was applied.

On the sixth day the patient was able to walk; the knee had regained complete extension. On the seventh day he was dismissed from the hospital. On the fifteenth day when the sutures were removed, there was 90 degrees of active motion. There was excessive bloody effusion in the joint. At five weeks the patient returned to his work as a traffic patrolman. Slight effusion persisted in the knee until approximately June 5, 1951. There has been none since that time. The patient has continued to be normally active, he can go into a complete squatting position, can use the knee in every way as he does his other knee and has had no further trouble with it. It is now four years since operation. Recently he chased a thief three blocks and caught him.

CASE 3. A female, aged seventy-two, in whom the diagnosis was degenerative arthritis, had had six to ten years of gradually increasing pain in the right knee. For one month the pain had been very acute, especially on getting up from a chair and going up and down stairs. There was a history of three falls on this knee in the last twelve years.

Examination revealed a slight flexion contracture of the knee in standing position. It could not be completely extended passively. There was definite grating beneath the patella on flexion and extension.

Roentgenograms revealed an advanced degenerative arthritis. Conservative treatment was instituted but the knee became progressively worse.

Arthrotomy of the knee was carried out on September 11, 1950. The lateral meniscus was found to be badly frayed and the medial meniscus was loose. They were excised. There was a loose body, five to seven millimeters in diameter, in the intercondylar notch. The patellar cartilage was very thin and badly worn, and there was definite wearing of the condylar cartilage opposed to the patella. A patellar prosthesis was applied. The patient was able to walk with the knee in complete extension on the eighth day. On the fourteenth day, she was dismissed from the hospital. In four weeks the knee could be flexed 90 degrees; there was complete passive extension and almost complete active extension. There was considerable tenderness over the tibial collateral ligament. The patient was wearing high-heeled shoes and was advised to wear oxfords. The patient continued to have pain in the knee, which limited her activity. She could not gain more than 90 degrees of flexion. There was no effusion. Physiotherapy was discontinued. Within two months the knee had greatly improved, and she was able to walk on it without pain. At three years and three months the knee was re-examined. There was no effusion. There was complete extension against gravity, and there was 95 degrees of flexion. She was able to do anything she wanted to do, and the knee felt just like the other one except that it would not bend quite so far.

This woman had a fairly small patella. The large size prosthesis was used without trimming the patella. It is now my opinion that her convalescence would have been much faster had the medium-size patellar prosthesis been used. At that time, this was not available.

CASE 4. A male, aged fifty, had bilateral degenerative arthritis of the knees with internal derangement of the left knee. The following history was taken May 18, 1945. Two weeks before he was seen the patient had fallen and twisted the right knee severely. He was unable to straighten it. The knee felt insecure, there was definite giving-away, and it was quite painful. Marked effusion and flexion contracture were present. This knee gradually recovered with conservative treatment.

On June 6, 1950, the patient was again seen and at this time his left knee was painful and swollen. He was unable to bend it and unable to extend it completely against gravity. There was tenderness over the medial meniscus. There had been definite giving-away of the knee. There was an effusion in it. He was walking with the knee flexed. Roentgenograms made at that time revealed partially calcified menisci. Conservative treatment was instituted, but on June 12, 1950, the knee locked and he could neither bend nor straighten it.

Arthrotomy of the left knee was carried out on June 15, 1950. The articular surface of the patella was almost completely worn off. There was a corresponding area of chondromalacia with eburnation of the bone

FIG. 9

on the lateral condyle of the femur where it opposed the patella. Both menisci were partially calcified and were fractured and displaced. These were excised completely. A patellar prosthesis was applied. The patient began weight-bearing on the eighth day. He was dismissed from the hospital the tenth day, walking without assistance. No physiotherapy was given after he left the hospital. At nine weeks he was walking with an almost normal gait and with the knee going into complete extension. At three months he returned to work.

There was no effusion in the knee. When seen four months after the operation the knee had continued to improve in strength and he was able to work on it three days a week from 2:30 A.M. until 6:00 P.M. His occupation is that of a vegetable-peddler and he gets on and off his vegetable-cart many times a day. At four years after the operation, he had a full range of pain-free motion, the patella felt perfectly smooth, and he was able to get down on his knees. His only complaint was that his knees ached with weather changes, especially in cold weather.

On July 20, 1954, the *right* knee suddenly locked and on July 28, 1954, it was similarly operated upon and made an even more rapid recovery. He still works as a vegetable-peddler, using a horse cart. Roentgenograms of these knees were made in March 1955 (Fig. 9).

CASE 5. A female, aged fifty-seven, had a fracture of the right patella. The patient had fallen from the steps of a bus and had injured her right knee on October 23, 1951. Roentgenograms revealed a comminuted fracture of the patella.

Open reduction was carried out on October 25, 1951. The lower part of the patella was found to be badly fragmented, but a central pie-shaped portion of it was intact. The upper half of the patella was split in two pieces with one large and one small fragment. There was a complete tear of the anterior capsule and complete severance of the extensor mechanism. The fragments were gathered together and the cartilage surfaces, which showed some evidence of previous chondromalacia, were removed with a rongeur. Some of the bone at the fracture site was removed to permit the patella to be inserted into the prosthesis without trimming its edges. This results in some slack in the lateral expansions of the capsule which facilitates their suture and prevents strain on the suture line during subsequent early function.

This procedure is used only in fractures. Removal of a central transverse section of the patella to make it fit the prosthesis has been considered for other conditions. It would probably work but has not been tried.

The screw in the prosthesis was passed through the larger of the upper and lower fragments. Lateral expansions of the capsule were closed with interrupted 32-gauge stainless-steel sutures. On the second day the patient walked with a cane. On the fourth day she was dismissed from the hospital. On the eleventh day when the skin sutures were removed the patient was walking with a normal gait. At three weeks after the operation, the patient had a normal range of motion and was able to go up and down stairs normally. She was unable to extend the knee completely against gravity. She had no physiotherapy or any special muscle training. She returned to work as a clerk in a department store three weeks after her injury. She has continued to be normally active. She still has slight atrophy of the quadriceps.

The author has used this prosthesis successfully in over forty knees. These cases are presented in detail in Table 1. Some of the patients were operated upon over five years ago. There have been four failures due to infection. There have been no mechanical failures in this series. In two patients, convalescence was prolonged to several months because the prosthesis used was too large.

Other surgeons have used this prosthesis in one or several cases. The principal indication in these cases has been simple chondromalacia. The author considers this to be one of the more important indications for the use of the prosthesis, second only to its use in extensive reconstructive procedures.

The most important lesson derived from this experience is that the restoration of a normal, or nearly normal, quadriceps extensor mechanism is a decisive factor in the success of knee-joint reconstruction and outweighs all other factors in importance. Such a restoration is feasible through the use of this prosthesis.

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A SELF-ADJUSTING NAIL-PLATE FOR FRACTURES ABOUT THE HIP JOINT *

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It would be well for those reading this article to refer to Dr. James A. Dickson's publication in the October 1953 issue of *The Journal of Bone and Joint Surgery,* entitled "The Unsolved Fracture". The following is a quote from this article which so well presents the difficulties of internal fixation of the femoral neck.

"The method most generally used for internal fixation of fractures of the femur is the Smith-Petersen cannulated trifin nail. Despite the number of excellent results with its use, I am sure that it does not fulfill in all cases one of the primary requisites of complete immobilization. If an engineer or cabinet maker had a similar problem, he would use an angle support or brace and would not depend on a nail alone. For several years, I have been using the Jewett-type trifin nail, which gives additional fixation to the shaft, and so, of the devices now available, comes nearest, in my opinion, to fulfilling the necessary requirements. My experience indicates that this type of nail, properly placed in low position in the neck so that it practically rests on the calcar femorale, together with the added shaft fixation, apparently increases the stability and thus increases the likelihood of bone healing at the fracture site. . . . The nail should extend about two thirds of the way across the head fragment in an attempt to provide maximal support and still give sufficient clearance to avoid protrusion of the nail if impaction or absorption of the bone should take place. When the fracture is well reduced and adequately fixed, however, absorption of bone at the fracture line during healing is minimal.

"Even with the advantages of shaft fixation, it is sometimes extremely difficult to obtain complete immobilization in the case of some subcapital fractures, in which the small proximal fragment is balanced on the top of the nail and the resulting shifting at the fracture site may give rise to bone absorption and a tendency toward proximal protrusion of the nail. In attempts to minimize this possibility, special nails have been used, such as those designed by Dr. Carl Badgley and by Dr. Willis Pugh; they have the advantage of shaft fixation, but are so constructed that the blade can back out if any absorption should occur at the fracture site, thus assuring continued impaction and maintenance of position."

The type of hip nail herein described was devised primarily for fractures of the neck of the femur. It was designed to incorporate the desired shaft fixation in an appliance which would prevent distraction of the fracture fragments and at the same time reduce the possibilities of the nail's penetrating the joint.

Numerous methods of internal fixation have been devised for treatment of fractures of the femoral neck, some of which have contributed, all of which, however, have left much to be desired. Since the introduction of Smith-Petersen's three-flanged nail, much

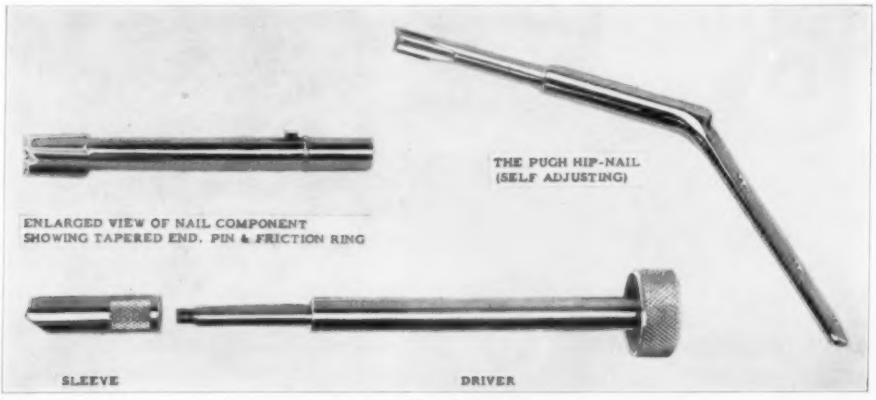

FIG. 1

Illustration of the self-adjusting hip nail.

* Shown in the Gadget Exhibit at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 1953.

work has been done and many contributions have been made. To mention only a few: Moore's threaded pins, the lag screw described by both Henderson and Godoy Moreira

FIG. 2-A

FIG. 2-B

Figs. 2-A and 2-B: A female, aged sixty-four. The anteroposterior and lateral roentgenograms, made on February 27, 1954, showed an intracapsular fracture of the left hip.

FIG. 2-C

FIG. 2-D

Anteroposterior and lateral roentgenograms made sixteen days later, on March 15, 1954.

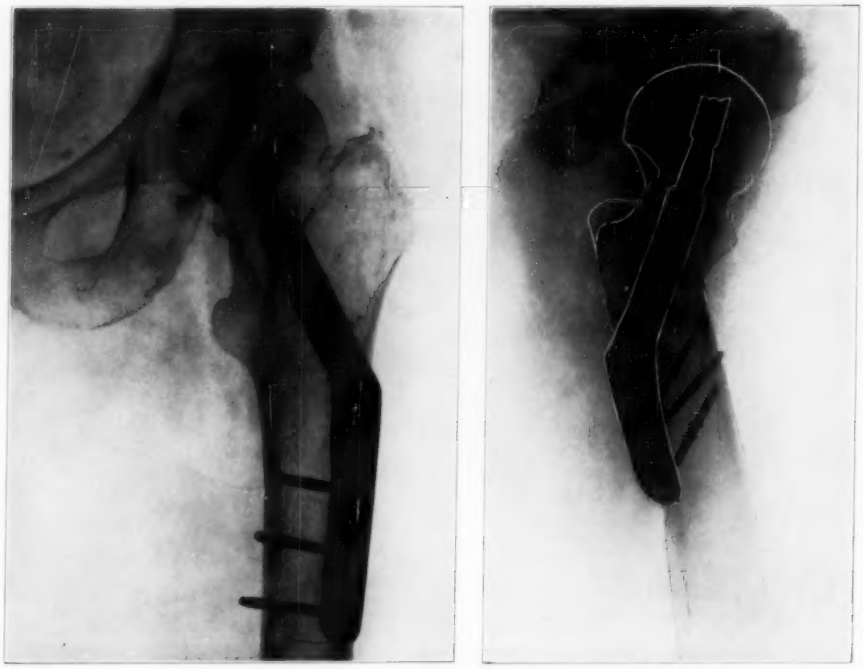

FIG. 2-E FIG. 2-F

Anteroposterior and lateral roentgenograms made three and one-half months later, on June 23, 1954, showed solid union. (The roentgenogram in Fig. 2-F has been retouched.)

and their respective associates, and the one-piece construction of the three-flanged nail and plate by Jewett and his coworkers. Although the nail to be described had been designed originally for femoral-neck fractures, it has been found that it is equally adaptable and has decided advantages over other types of internal fixation for intertrochanteric and subtrochanteric fractures, because of its unusual strength and adjustability.

The structure of the nail is quite simple; it consists of two main parts. A keyway is provided on the inner surface of the tube, and a pin or key is fixed in the nail portion to match the keyway, in order to prevent rotation of the nail. A friction ring is provided near the distal end of the nail to furnish tension, so that the nail is prevented from backing out of the head should absorption occur about the end of the nail. This ring is similar to a piston ring in a gasoline engine.

The friction ring is most important, as it allows the necessary clearance between the nail and the tube, permitting the nail to slide and insuring adjustability by eliminating binding. In constructing a type of internal fixation which is adjustable and can be depended upon in every instance not to bind, while still offering enough resistance to keep the flanged portion of the nail from backing, or falling, out of the head, the friction ring offered the most suitable, simple, and practical method. The tube is of sufficient length to reduce side stress which also prevents binding. During the experimentation with this idea, in cooperation with engineers, it was conclusively demonstrated that, with the use of a short-tube construction, complete ability to slide within the tube could not be assured where side thrust is encountered. The long tube is the angle support or brace which an engineer or cabinet maker [2] would use.

With other types of fixation, which do not provide for adjustment, one of two situations may arise. First, the nail will penetrate the femoral head and into the acetabulum,

or, in case of a very hard femoral head which does not permit much penetration, the fragments will be distracted and non-union is thereby practically assured. This feature is the

FIG. 3-A

FIG. 3-B

FIG. 3-C

FIG. 3-D

Fig. 3-A: A female, aged eighty-four. The anteroposterior roentgenogram, showing an intracapsular fracture of the right hip, was made on May 13, 1954.

Fig. 3-B: Roentgenogram showing reduction during surgery.

Figs. 3-C and 3-D: Roentgenograms made on May 18, 1954, showing initial fixation at surgery with the self-adjusting nail-plate. (The roentgenogram in Fig. 3-D has been retouched.)

FIG. 3-E

FIG. 3-F

Anteroposterior and lateral roentgenograms made three weeks later, on June 8, 1954, showed impaction of the fracture ends.

main improvement in the nail and so far there has been no report of failure of the nail to slide within the tube. Thus the fracture fragments are kept in constant contact or impacted.

Another advantage is the construction of the end of the nail. This consists of the conventional trifin or three-flanged-nail element. Each of the three fins is tapered along its side and end, a construction which provides an additional wedging grip on the head. Naturally, since the hazard of penetrating the hip joint has been reduced, it is desirable to drive the nail in close proximity to the articular margin of the head and because of the construction of the nail an effective grip on the head is provided.

Figures 2-A through 3-F illustrate the application of the nail in two intracapsular fractures, and Figures 4-A through 4-C illustrate an intertrochanteric fracture in which the nail was applied.

SUGGESTED SURGICAL TECHNIQUE

The fracture is reduced by manipulation, but if a satisfactory reduction is not accomplished by closed means, we do not hesitate to do an open reduction. An anatomical alignment, or possibly slight but not extreme valgus of the fracture, from the author's experience, as well as that of others using the nail, seems to offer the best results.

It is logical to assume that union will be accelerated by having as much of the surface areas of the fracture fragments as possible maintained in constant contact during the healing period. When the head is in extreme valgus, as is the case when one attempts to convert a so-called Pauwels Grade 3 to a Pauwels Grade 1 type of fracture, the surface areas in actual contact are greatly reduced, perhaps as much as 50 per cent. Reports indicate that this has been the cause of failure in several cases[1, 5, 7, 8, 13].

The operative procedure is essentially the same as for any nailing operation in which

guide-pin technique with roentgenographic control is used. The most suitable angle for the nail has been found to be 135 degrees. The placement of the nail with relation to its position in the neck and head is all-important; this, of course, applies not only to this nail, but to all nails. The nail should be placed in the inferior half of the neck and head, or at least inferior to the mid-line in the anteroposterior plane. It should be in bull's-eye position or slightly posterior to the mid-line in the lateral plane. This placement reduces the likelihood of rotation of the head fragment off the end of the nail as impaction occurs. In this way, if any rotation occurs as the fracture fragments are impacted, the nail rotates into a few degrees of valgus, which is desirable. It is necessary to drill or ream a hole through the cortex and up the neck of the femur of sufficient size to accommodate the tube portion of the nail. A cannulated reamer with a diameter of one-half inch is used.

FIG. 4-A

A male, aged fifty-six. The roentgenogram, made on February 22, 1953, showed a comminuted intertrochanteric fracture of the right femur.

The nail is then inserted into the hole and is maintained in its shortest position, the driver with

FIG. 4-B

FIG. 4-C

Anteroposterior and lateral roentgenograms made nine months after operation.

TABLE I

SUMMARY OF RESULTS ACCORDING TO TYPE OF FRACTURE

(Pauwels' Classification)

Type of Fracture	No. of Cases	Union	Non-Union
Pauwels Grade 1 (0 to 30 degrees)	2	2	0
Pauwels Grade 2 (30 to 50 degrees)	13	11	2
Pauwels Grade 3 (50 to 90 degrees)	14	12	2
Total	29	25 (86.20 per cent.)	4 (13.79 per cent.)

the sleeve being used. The plate is then clamped to the shaft of the femur. The sleeve, which maintains the nail closed, or in the shortest position, is removed, the driver is reinserted, and the nail component is driven home (well up to the articular cartilage). The plate is then secured to the shaft with screws. The procedure is extremely simple and other than drilling the one-half inch hole, the technique is the same as for other nail and plate combinations.

AFTER-CARE

The after-care is no different from that following other types of fixation. However, because of the more adequate fixation with this nail, we allow the patient to sit up in a chair a day or two after operation and to use a walker within a few days. In this

FIG. 5-A

FIG. 5-B

Fig. 5-A: Anteroposterior roentgenogram made one week after surgery. (The roentgenogram has been retouched.)

Fig. 5-B: Anteroposterior roentgenogram made six months after surgery. (The roentgenogram has been retouched.)

respect the cooperation of the patient must be sought, as it is not felt wise to permit much weight-bearing until union is stable. Even then, caution is followed and usually full weight-bearing is not permitted for from four to six months, even though, in a number of cases, roentgenograms may show stable union as early as eight to ten weeks after operation.

RESULTS

The results in the first group of cases in which the nail was used are shown in Table I. The quantity of nails was limited in the early stages of this study and consequently in an attempt to demonstrate whether this nail was an improvement, the cases were selected. The majority of these patients had Pauwels Grade 2 and Grade 3, or the more vertical types of fractures. It was assumed that the Pauwels Grade 1, or the more horizontal fractures, would probably give good results regardless of the fixation used. In this tabulation, since the majority of cases are Pauwels Grade 2 and Grade 3 fractures, or the more vertical type, the percentage of failures is considered low. This opinion is further substantiated when these results are compared with some of the others previously reported in which the type of femoral-neck fracture was not taken into consideration. In the cases listed below the postoperative follow-up was twenty-two to thirty-two months. This time is considered sufficient to determine the fate of the fracture and avascular necrosis for the longer follow-up periods.

Total number of cases	29
Average age	69
Females	22
Males	7

There was one patient with definite evidence of avascular necrosis; however, the changes in this case were only minimal. In another case there was questionable evidence of this complication. One patient died six months after operation of a primary carcinoma of the lung. He had been ambulatory four months after operation, and roentgenograms made at that time showed stable union.

Observations

1. The nail did not penetrate the hip joint in any case.
2. There were no cases in which the nail kept the fracture distracted or failed to allow impaction.
3. The nail did not bend in any case.
4. Recheck roentgenograms at eight to ten weeks after operation in many cases revealed what appeared to be a solid union, indicating possible acceleration of the healing process.
5. In some of the cases comminution of the neck was evident. In these cases the nail retracted as much as one-half inch as impaction occurred and union resulted (Figs. 5-A and 5-B).

Analysis of Failures

In two cases reduction was lost because of insufficient tension of the friction ring, allowing the nail to back completely out of the head. In another two cases there were technical difficulties; that is, there was inadequate roentgenographic control and placement of the nail was not satisfactory.

Treatment of Cases with Failures

One patient was first treated with an osteotomy, which failed. A prosthesis was applied later. Two patients were treated with an Eicher prosthesis, and one patient refused further surgery.

An attempt was made to classify the results on a functional basis but because of the variations in age, as well as the variation in the general physical status of these patients this was deemed impractical. In the cases in which solid union occurred the result was considered *good* or *satisfactory*. The complaint of pain has not been prevalent in the group of patients whose fractures united. Even in the cases in which avascular necrosis appeared to be developing, the complaint of pain has been negligible so far.

Later in this study eighteen cases of intertrochanteric and subtrochanteric fractures were treated, with good results.

NOTE: The author wishes to express his gratitude to Dr. Joseph C. Lawrence and Dr. John H. Sterne for their help in the compilation of this study. The author also wishes to express his thanks to Mr. Clyde E. Yost for his untiring efforts in helping to solve the engineering principles involved. The helpful criticisms of Dr. J. A. Dickson and of the late Dr. M. S. Henderson and the valuable information gained from discussion of the nail with these surgeons are greatly appreciated.

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SIMPLE MODIFICATION OF THE SMITH-PETERSEN NAIL DRIVER

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Since the introduction of the three-flanged nail by Smith-Petersen, many modifications have been made in both the nail and the technique of its use. The cannulation of the nail for use with a guide wire and roentgenographic control was an expected application of a principle previously described by Richard for other fixation apparatus. Subsequently, Watson-Jones described the complication of acetabular penetration with intrapelvic protrusion of the guide wire.

This complication has been attributed to a number of factors, among which are: (1) the use of a guide wire of too light a gauge, (2) the use of a bent guide wire, (3) the bending of the guide wire during the insertion, (4) insufficient traction which permits fracture motion to bend the guide wire, (5) the attempt to correct faulty placement of the guide wire while driving the nail, (6) a defect in the guide wire, or (7) a dirty or defective nail cannula.

FIG. 1

The windows in this tubular cannulated driver permit constant visualization of guide wire.

In nailing procedures performed by the inexperienced surgeon, acetabular penetration with intrapelvic protrusion of the guide wire still occurs. By appreciating and avoiding the above etiological factors, this complication can be obviated. Prior to the insertion of the selected nail, the patency of the cannula should be verified by the passage of an accessory guide wire. In addition, most experienced surgeons remove the driver at intervals during the course of insertion of the nail to observe the passage of the nail over the guide wire. Some even resort to twisting the wire at the time the driver is detached.

Although the detachment of the driver consumes only a minimum of time, the author feels that the elimination of this necessity by a simple modification of the driver is worth while. The standard driver for insertion of the Smith-Petersen nail, irrespective of which modification, is basically a solid-walled cannulated metal tube. The presence of multiple windows in the wall of the tube permits constant visualization of the passage of the nail over the guide wire (Fig. 1).

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REPORT OF THE TRAVELS OF THE EXCHANGE FELLOWS

By Daniel C. Riordan, M.D., New Orleans, Louisiana

Four Americans and one Canadian met on board the *Queen Elizabeth* on April 20, 1955. The Americans were: Albert Ferguson of Pittsburgh; Charles Gregory of Indianapolis; Leonard Goldner of Durham, and Daniel C. Riordan of New Orleans. Cameron Allen of Vancouver was the Canadian Fellow. The crossing of the Atlantic was made in clear, cold, weather; it was very enjoyable and included a tour of the ship's sick-bay and hospital, run by Dr. D. MacKay and Dr. F. M. Rust. We were also taken on a tour of the engine room and saw the new stabilizers in action.

The ship docked at Southampton on April 26, where we were greeted on board by Prof. Bryan McFarland, President, and Mr. J. I. P. James, Secretary, of The British Orthopaedic Association. We were passed quickly through customs thanks to the efforts of these two gentlemen. We had an enjoyable train ride from Southampton to London.

The first afternoon in London was occupied by a tour of the Royal College of Surgeons during which

Fig. 1

The Exchange Fellows: Standing (left to right) are Charles Gregory, Indianapolis, and Albert Ferguson of Pittsburgh. Seated (left to right) are Daniel C. Riordan, New Orleans, Leonard Goldner, Durham, and Cameron Allen, Vancouver.

we were led by its president, Sir Harry Platt. We were officially greeted at a dinner in the Royal College on this same evening.

The first week of the tour was spent in London. We made visits to the Middlesex Hospital, Guy's Hospital and its associated hospital at Orpington, Chailey, a hospital associated with St. Bartholomew's, the Royal National Orthopaedic Hospitals and its associated hospital, Stanmore. These visits were extremely well planned with well balanced programs of operations, formal presentations, clinical demonstrations and tours of the facilities of each.

On Wednesday, May 4, we flew to Paris, via Air France, in one of the new type British Viscount turbojet planes. Here, on May 5, 6, and 7 we attended the Joint Meeting of the British and French Orthopaedic Associations. By invitation, one of us, (D.C.R.), presented a paper on the "Radial Club-Hand." This meeting

gave us the opportunity of meeting the outstanding orthopaedists of France. It was very worth while. Paris in the spring is, of course, very beautiful and was thoroughly enjoyed.

On May 9, returning to London by air, we entrained to Liverpool. Liverpool and its environs are steeped in orthopaedic history. Here were the homes of Hugh Owen Thomas and Robert Jones, who have so tremendously influenced the development of orthopaedic surgery. It made one feel much closer to orthopaedics to see the places where these men worked and to see the libraries and the other noble memorials commemorating the birth of orthopaedics in this area. A delightful program was presented at the Royal Southern Hospital and a very interesting evening was spent at the Liverpool Medical Institution. Here are many of the books and papers and many of the personal belongings of both Hugh Owen Thomas and his nephew, Sir Robert Jones.

On the following day, there came the visit to the Robert Jones and Agnes Hunt Hospital, at Oswestry, where we saw the original unit of this hospital in which Dame Agnes Hunt started her outdoor method of treating crippled patients. A delightful tour of Wales followed.

We then visited the Davy Hulme Park Hospital in Manchester and the Manchester Royal Infirmary. On May 15, the group traveled to Edinburgh and spent a very full three days there, during which there were visits to the Edinburgh Royal Infirmary, the Princess Margaret Rose Hospital, and the Wilke Research Laboratory. Coupled with this were sight-seeing tours of the city of Edinburgh and a tour of the Border. The stay in Edinburgh was closed by a tour of and delightful dinner at the Royal College of Surgeons of Edinburgh.

We next traveled to the Bridge of Earne Hospital, Perthshire, and from there to Glasgow. In Glasgow, the Victoria Infirmary, Royal Infirmary, and Killearn Hospital were all visited and many interesting cases were seen. The stay in Glasgow concluded with a tour of Loch Lomond and the Trossachs.

We next visited the Birmingham Accident Hospital, a unique institution in which orthopaedists do the complete treatment of traumatic cases, with the exception of neurosurgery related to the head. Nottingham was also visited with a brief stay at the Harlowe-Wood Hospital. In Mansfield, the Chesterfield and North Derbyshire Orthopaedic Hospital was visited and in Sheffield the Royal Infirmary was visited. A trip to the paraplegic center at the Lodge-Moor Hospital was also made in Sheffield. We made a delightful visit to Stratford-on-Avon on May 28. The group attended a performance of *Twelfth Night*, in the Shakespeare Memorial Theatre, in which the female lead was played by Vivian Leigh and the male lead by Sir Laurence Olivier.

Three days were then spent in Oxford University. Here the Wingfield-Morris Orthopaedic Hospital and the Nuffield Orthopaedic Center and the Radcliffe Accident Hospital were visited.

In Bath, the Bath and Wessex Orthopaedic Hospital was visited. In Bristol, the Winford Orthopaedic Hospital was visited. In Exeter we toured the Princess Elizabeth Orthopaedic Hospital and, also, made a brief visit to the medical library of the Exeter Cathedral where many ancient and priceless volumes on medicine are housed.

The final program of the tour was given at The London Hospital, in London, on June 6. The tour was officially closed by a dinner of the A.B.C. Club, held at the Savoy Hotel.

Most of the hospitals visited were ancient and steeped in the history of medicine and surgery. Some of the hospitals were war-time huts which are still being used, and, apparently, will be used until more permanent type of buildings can be constructed sometime in the future. The type and quality of orthopaedic work that was seen was of the highest and was all well founded on the fundamentals. The research was being ably done, in some instances in spite of inadequate facilities.

The types of cases seen varied considerably in the different hospitals visited and it is impossible here to go into any great detail. In the fracture wards we saw large numbers of patients suffering from Paget's disease. Most of the wards had at least two or three patients with fractures of the femur, suffering from Paget's disease. The treatment in these cases varied from conservative treatment in traction to open reduction and internal fixation with a nail and a plate or with intramedullary nails.

Tuberculosis of bones and joints is still a fairly widespread problem in Britain, although it has declined considerably since the advent of the antibiotics effective against tuberculous organisms. It was interesting to note that there has been a considerable swing away from the conservative treatment which was advocated for so long by British orthopaedists. Everywhere we went we saw patients being treated by open operations with the removal of abscesses and necrotic debris. This was combined with the use of antibiotics. Because of the large number of cases, most centers have a fairly wide experience in treating tuberculosis of the spine and the paraplegia that occasionally results. Drainage of the abscesses through an anterolateral approach or costotransversectomy with closure of the wounds was being used with considerable success.

Many cases of congenital dislocation of the hip were seen and the methods of treatment varied considerably. Conservative reduction and immobilization in abduction and external rotation was used in some instances. In others, abduction splints allowing motion were used. In one institution, open reduction and excision of the limbus was used, followed by rotation osteotomy and plaster for two or three months. Early mobilization was then allowed. The results of fifty cases seemed very encouraging.

One of the most interesting aspects of the entire trip was the varied methods of treatment being used

for osteo-arthritis of the hip or for the arthritis subsequent to fractures of the neck of the femur. We saw a beautiful series of cases with a long-term follow-up on the use of the McMurray type of osteotomy. The impression one gained from this was the improvement after a McMurray osteotomy continues almost indefinitely. The cystic areas and sclerotic areas in the head of the femur and the acetabulum nearly always seemed to disappear as the bone reconstituted itself, and, in many cases, a joint space was re-formed. The longest follow-up in this series was twenty-five years. The significant thing about this was that the patient's gait was quite good. Most of the patients were almost, or completely, pain free. In several places, Smith-Petersen type arthroplasties were seen, but in only one institution did the results seem to be good enough to warrant continuation of the use of the method. Resection of the head and neck of the femur, in unilateral or bilateral cases, was seen in another institution and the results here seemed surprisingly good. In still another hospital, a series of these resections had been done together with an osteotomy of the shaft. These results did not seem quite as good as those from the former method, without the osteotomy.

As one might expect, the use of the acrylic Judet type of prosthesis has led to many difficulties and the salvage consisted of either replacement with another similar type of prosthesis or a different type of prosthesis, or resection of the head and neck, or a Whitman reconstruction, or occasionally, a hip fusion. In the latter cases, the prosthesis was left in and a Trumble type of fusion was done.

In one paraplegic center that we visited, a high type of work was being done and a skilled team of doctors and nurses were giving the patients excellent care. No special equipment or beds were being used, but an adequate program of initial treatment and good follow-up nursing care were producing excellent results in the care of these unfortunate individuals.

In several of the hospitals visited, orthopaedic operations on the shoulder, hip, or spine were being done under hypotensive anaesthesia. In some hospitals the method was being used widely and large experience had been accumulated; in others, it was only being used occasionally and with great caution. To this writer, it would seem that the method has its greatest advantage in hip surgery, or in massive procedures around the hip.

Most of the orthopaedic hospitals have been established for a long time and, of necessity, have had their own brace shops as a part of their establishments. This had led to highly individualized types of construction. In many cases the craftsmanship is unique.

With the present-day emphasis on rehabilitation, it was refreshing to see that in Great Britain it is not anything new or separate from orthopaedics, but actually is simply a part of the general orthopaedic care of any given patient. In brief, it may be said that the orthopaedic care of a patient starts with first-aid treatment and continues until he returns to his job or some other form of employment.

The open air type of hospital ward is still quite common. The only change that has developed in this type of hospital is the inclusion, in many of them, of folding glass doors which can make the open wards partially, or completely, closed during the winter months. In one institution they still have only canvas covers to exclude the cold and snow. In spite of this, most of the patients seem to be quite healthy in appearance and did not seem to be bothered by the cold.

It is the opinion of our group that the value of a fellowship tour, such as this, is very great. It is a wonderful, refreshing way of having a complete review of orthopaedics which comes at an opportune time in the orthopaedic life of the individual. If this tour were granted to younger men at the Resident level, I am sure that many of the things seen would not be appreciated. Under the present method of selection, it seemed that the time for the tour is ideal, as far as the experience of the participant is concerned. In addition to this, there can be no substitute for the personal contact, not only with the older, outstanding men of orthopaedics, but with the men of the same age as the visitors. I am sure that this will be of great benefit to orthopaedics as a whole, on both sides of the Atlantic. It is the fervent hope of this group that the American, Canadian, and British Orthopaedic Associations will perpetuate this type of traveling fellowship. The individual who makes such a trip will benefit by having a much broader outlook and understanding of the field of orthopaedics, and all of the orthopaedists, especially the younger men in training, who come in contact with a man who has had a fellowship will benefit.

The author was fortunate enough to have been able to record the voices of some of the men visited on this tour and this, no doubt, will be of considerable personal interest to the members of the tour and to the residents who will have the opportunity of hearing the men who were met during the fellowship.

All of this group from the United States and Canada are most grateful for having had this opportunity of visiting Great Britain and will do their utmost to spread the information gathered during this fellowship.

ORTHOPAEDIC SURGERY IN NEW ZEALAND

Prof. Robert I. Harris, one of the two Sims Commonwealth Traveling Professors appointed for the year 1955, recently completed his visit to New Zealand, the first step in his Sims tour. A short account of the visit with comments taken from a letter by Prof. Harris follows.

New Zealand is a country of 2,000,000 people on two large islands of 103,736 square miles, situated 1200 miles due east of Sydney, Australia. The four largest cities are Auckland (pop. 350,500) and Wellington, the capital of the country (pop. 217,800), both situated on the North Island; Dunedin (pop. 97,900) and Christchurch (pop. 182,800) on the South Island. Many smaller cities and towns are scattered throughout the two islands. There is one medical school at Ogago University in Dunedin which graduates about 125 students each year. The six-year course covers basic sciences and medicine. The final year is a clinical year spent in the hospitals of the four cities mentioned above. Graduation is followed by a year of general internship which is compulsory. Those planning to practise surgery then undertake two years of general surgical training. At this stage the young New Zealand surgeon usually "sits for his fellowship" either in the Royal Australasian College of Surgeons or in the Royal College of Surgeons of England. Those planning to become orthopaedic surgeons then embark upon two or three more years of orthopaedic training either in New Zealand or Great Britain or both. Many have spent some time in the United States and a few have studied in Canada. Travel and study in dollar countries, however, is very difficult. There are few dollars available for this purpose. The separation of the world into dollar areas and sterling areas is a tremendous barrier to the interchange of knowledge in the world of medicine and one is very conscious of this in New Zealand.

There are good orthopaedic departments in the hospitals of the four large cities and in many of the smaller cities. In towns of smaller size and more remotely situated the urgent work is done by local surgeons who sometimes are general-practitioner surgeons. Patients with elective orthopaedic conditions are sent to the larger hospitals. Where orthopaedic services exist it is usual for these services to be responsible for fractures.

The high standard of medical practice in New Zealand is due, in the first place, to good education. The Scotch tradition permeates the primary and secondary schools. It is not surprising that the Edinburgh tradition prevails in the medical school. The school is situated in DunedEn which is the center of the Scotch settlement. It is a city whose streets are named after Edinburgh's, and where Scots predominate. The product of its training is worthy of the great tradition from which it derives.

New Zealand doctors are well informed and well read. Most of them have studied abroad, either in their early graduate days or later in their careers. Nearly everyone is saving money for a trip "Home", that is, to Great Britain, to bring himself up-to-date with respect to the most recent advances in his particular field of interest. The effect of great distances is very evident. A refresher course means much time, much money, and a long journey. In July, the April numbers of the *British Medical Journal* and *The Lancet* were just arriving.

There are some interesting aspects of orthopaedic surgery in New Zealand which are worth recording. Certain congenital deformities are much more common than in North America. Club-foot is very common among the Maoris and Polynesians. Several of the members of a large family may have the deformity. Since the Polynesians usually go barefooted, they suffer less disablement than might be expected. They appear comparatively late for treatment and come long distances. It is not easy to get them back for review or to continue treatment. Once they leave the hospital, as a rule, they disappear. Consequently a practical form of treatment has been a modification and elaboration of Brockman's stripping operation in which the medial side of the foot is exposed. The tendon sheaths and joint capsules are excised; the tendons are lengthened: and capsulotomies are performed when necessary to a full correction of the deformity. The results of this plan of treatment at Middlemore Hospital at Auckland were impressive in that complete correction of severe deformity had been obtained in a few weeks with excellent function.

Slipping of the upper epiphysis of the femur is common. The problem of treatment is the same as in North America. Early cases with minimal displacement do well with simple nailing without correction of the slipping. Complete separation of the epiphysis which has occurred suddenly often does well if the epiphysis can be replaced with a minimum of trauma. The more severe displacements which have occurred gradually, all too often do badly under any form of treatment because of avascular necrosis of the head of the femur.

Peroneal spastic flatfoot is common in New Zealand and the evidence that this condition is due to congenital fusions between major tarsal bones is generally accepted. The calcaneo-navicular bar seems more common than elsewhere. Prof. Harris writes that he saw as many cases in New Zealand in three and one-half weeks as he had seen previously in the ten years in which he has been interested in this condition. Moreover he saw convincing evidence of improvement obtained by resection of the syndesmosis. It had seemed clear that in properly selected patients, such as adolescents who have an incomplete bar, resection is well worth while.

Congenital amputations and agenesis of the extremities seem common and these are well treated by individually designed prostheses.

The New Zealand Orthopaedic Association held its Annual Meeting in Wellington while Prof. Harris was there which enabled him to share in the program. He writes that it was an interesting and stimulating occasion, and adds: "The influence of Boston extends even to New Zealand as I learned to my embarrassment when I was called upon at a clinicopathological conference in Wellington to recognize and discuss an obscure bone tumor of the lower end of the femur. It proved to be a parosteal osteoma which I had never before encountered. The pathologist who conducted the inquisition was Dr. Reed who had been trained in the art of educating the clinician by Dr. Mallory. It was indeed educative to me for I was able to recall one of my own patients who must have had this lesion although until now the diagnosis was sclerosing osteogenic sarcoma."

New Zealand has comprehensive social-security legislation which includes complete hospital and medical care for every citizen. It is financed by a 7.5 per cent. tax on income over and above the usual income tax which in itself is high. All public hospitals are operated by the Minister of Health. Hospital care and medical care in public hospitals is completely free. One consequence of this is the difficulty of getting older patients out of hospital when their treatment has been completed. Their surgical problem merges gradually into a custodial problem and, since they are more comfortable and receive better care than they possibly can receive at home, it is not surprising that they stay in hospital. The result is that too many beds are filled with custodial-care patients; too few beds are available for active-treatment cases; and great delay results in getting patients into hospital whose treatment is not urgent. It had been disclosed that it is not unusual for a patient with a hernia or one with an elective orthopaedic problem to wait more than a year to get into hospital.

Their problem of ensuring adequate medical care for every citizen has proved to be a vexed question and they agree that the perfect answer has not yet been found. Every thoughtful person would agree that no citizen should lack the advantages of prevention and treatment of disease and that governments have some responsibility in ensuring that these facilities are available. In most attempts to achieve these ends, however, the doctor has not been consulted. Too often the result has been a plan which seems to give the citizen something for nothing and determines the responsibilities of the doctor in the scheme without seeking his views. In consequence he is forced into opposition even though he may be in entire agreement with the principle that every citizen is entitled to adequate medical care.

It seemed fortunate that the solution of this problem is being sought through experimentation in some countries. This allows time for other countries to inform themselves of the issues and their magnitude. Such experience can be used wisely when the time comes to act.

J. ALBERT KEY

Dr. Key died suddenly in the garden of his country home in the Ozark country of Missouri on Sunday, August 7, 1955. Funeral services, attended by a number of his friends from different parts of the country were held in St. Louis on Tuesday morning, August 9, 1955. This notice will be followed by a memorial tribute to Dr. Key in a subsequent number of *The Journal*.

JOHN B. KELLEY
1898–1955

Dr. John B. Kelley, Chief of the Orthopaedic Service at the Worcester City Hospital, died on August 8. Dr. Kelley served in the United States Navy during World War I. He was a graduate of the New York Orthopaedic Dispensary and Hospital and for a number of years served as President of the Alumni Association of that organization. He was a member of The American Academy of Orthopaedic Surgeons.

Proceedings

THE AMERICAN ORTHOPAEDIC ASSOCIATION

Annual Meeting, 1955

The Sixty-eighth Annual Meeting of The American Orthopaedic Association was held at White Sulphur Springs, West Virginia, on June 19, 20, 21, and 22. It had been four years since The Association met at The Greenbrier. A more congenial and hospitable setting could hardly be imagined.

The meeting which had been planned with consummate thoughtfulness and skill by the President and Mrs. White will long be remembered as one of the most enjoyable and most successful.

The Scientific Sessions were confined to the mornings from 9:00 o'clock to noon; the program for the meeting was stimulating and well balanced. There was enough that was formal scientifically; the short morning sessions left the remainder of the day for informal discussion amidst congenial surroundings.

Among the many distinguished guests were: Mr. Philip Wiles of London, President-Elect of the British Orthopaedic Association, Mr. H. Jackson Burrows of London, Deputy Editor of *The Journal* (British Volume), and Prof. Carl Hirsch of the Karolinska Institutet of Stockholm.

At the first Scientific Session held on the morning of June 19, each of the American Exchange Fellows briefly reported his impressions of their memorable tour of British orthopaedic centers. They had been flown to Paris and had attended the Joint Meeting of the British Orthopaedic Association and the *Société Française d'Orthopédie et Traumatologie*. The entire tour had been a tremendous experience. It left a lasting impression which will remain among the richest of the professional memories of each of the men. Their observations were recorded as follows:

Dr. Albert B. Ferguson, Jr., Pittsburgh, Pennsylvania.

This was a very concentrated trip which went down very well while we were taking it, but needed considerable digestion afterward. Since it is impossible to cover the trip item by item, I have chosen to give a short review of the Birmingham Accident Hospital as a topic of some general interest. This hospital illustrates one possible method of handling trauma in the future and is designed solely for the care of injuries. Incidentally, the Hospital Staff found in caring for mass casualties (in this case, from a train wreck forty miles away) that the patients transported to the hospital were better cared for than those treated at the scene. A hospital team at the scene was able to add nothing to the care.

In order for such a hospital to exist the accident case must go by the doors of other hospitals in the area — this is possible under the Health Act, but would obviously pose problems in a free economy.

One thousand accident cases per day are brought in and are handled by a very small group of men in a hospital with two hundred and fifteen beds.

There are three teams, each one of which consists of two consultants, a registrar, two house officers, an anaesthetist, and a social worker. One team takes the accident flow, the second team is reserved for grave emergencies which would take the full time of the accident team, and the third team is used for the outpatient return visits. Each team changes places with another every twenty-four hours.

The patient flow is divided into the acute cases and those for return visit. The space devoted to acute cases is a long hall on the right side of which are twelve cubicles; directly opposite, running along the left side of the hall, is the grave emergency room, the x-ray room used solely for these cases, and two operating rooms with the anaesthetist shuttling back and forth between them. The patient is led out at the other end to be sent home or to be put in a hospital bed.

The space devoted to return visits consists of two large consulting rooms with view boxes and a separate x-ray department. Issuing from these consulting rooms is a dressing department and a plaster-cast department.

The dressing department is a marvel for those who like time-motion studies and efficiency. One physician has the patient led first to one side of his desk for examination and then to the other to two nurses equipped with instruments and supplies. The physician examines and makes notes for the record. Sterile supplies are passed by a sterilizing nurse over an intervening wall. In a three to four hour period three to five hundred patients can be seen. The only weak link in the system is the physician who apparently can only stand several hours of this routine.

Everything is done by printed form and check list from the ordering of a plaster cast to an x-ray.

The only dreaded clinic in the week is the physical therapy clinic, for here one's failures tend to congregate. It is obvious that too many failures would back up all the way along the line and eventually slow the system down.

(Continued on page 1109)

THE DEVELOPMENT OF ORTHOPAEDICS IN THE FAR WEST *

BY J. WARREN WHITE, M.D., HONOLULU, HAWAII

My interest in the Far West arose when, as an asthmatic child quite comfortable in the summer, I decided I would never live, when I grew up, where there was rugged winter weather. The starting of central heating in the fall usually initiated my respiratory difficulties and so it was natural that when the opportunity to go to Hawaii came at the close of my training in Boston, I had no difficulty in making the decision. The other element in my fascination for the West arose from reading my twenty-two-year-old Forty-Niner Grandfather's diary in which he related his experiences during that eventful period of his life, as well as the number of grains of gold he and his brother Charles panned every day in their modest claim in Sonora. This typical gold-rush town, located in a deep gulch, was close to the "Big Bonanza" of that area, about seventy-five miles east of San Francisco.

After a year or so of this rough existence, these brothers came back to Boston with considerably more than their shirts and started a brace-and-truss making establishment located on Cornhill. Their early records show they were the principal brace manufacturers for Buckminster Brown, our pioneer Boston orthopaedic surgeon. How it was that these forebears of mine selected this type of business, I have never been able to find out.

The son of one of these brothers, Herbert Warren White, my father, born on the slopes of Bunker Hill, was sent to Harvard Medical School to become a member of the firm and an orthopaedic surgeon. In those days of the brace-and-buckle orthopaedist, this sort of work did not appeal to him and he settled in Roxbury, a suburb of Boston, as a general practitioner, where he raised his family, sending three of his four children to medical school. It was not until the next generation and a combination of happy circumstances in which Dr. Painter, Dr. Osgood, and Dr. MacAusland played important roles, that I became what my father was supposed to have been. C. W. White and Company, co-originated by my grandfather and his brother, is still on Cornhill where it started so many years ago.

The distressing ignorance of the average New Englander and Easterner about things west of the Mississippi has urged me, also now a Westerner of several years standing, to endeavor to cast some light on what has happened in the last momentous half century in the western third of our country as regards the development of our specialty. We have learned, through the help of some of our historically-minded orthopaedists, about the pioneers in the East, but with the exception of Dr. Orr, a Westerner himself, few have written about the fastest-growing part of our country, which I am calling the Far West. This Far West includes the Territory of Hawaii, which is further west yet. It is still not a state, as you well know, but is a real part of our country, as many of you who have visited it have found out.

The name "Far West" has been chosen deliberately, as I have been much interested, since returning to Hawaii, in the Western Orthopedic Association, an organization most of our members are not acquainted with, but which had its organization meeting a year before the Academy. Its geographical boundaries comprise that part of our country west of the eastern border of Colorado, that is, the Rocky Mountains and Pacific Coast area, roughly, the Mountain and Pacific Time Zones. It makes up about one million of our three million square miles.

Dr. Orr, who has materially helped me in this paper, gave a brief account of the history of orthopaedic surgery in the western part of the United States before 1900, in his

* Presidential Address presented at the Annual Meeting of The American Orthopaedic Association, White Sulphur Springs, West Virginia, June 21, 1955.

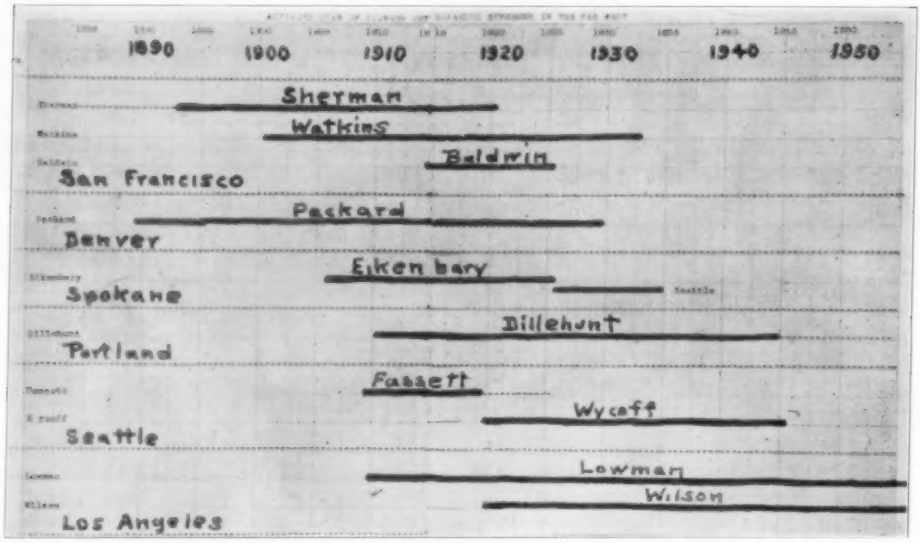


CHART I

Activity span of pioneer orthopaedic surgeons in the Far West.

Instructional Course on the History of Orthopedic Surgery at the Academy Meeting of 1947. The scope of my Address is more limited and covers the period after, rather than before, the start of this century. The average orthopaedic surgeon is so uninformed about our early history in this area that I have felt it to be of sufficient importance to devote my Address to it, calling particular attention to a few of our outstanding orthopaedic pioneers.

The growth of the western part of the United States has been so phenomenal that a few words calling attention to it are justified. The ceding to us of this distinct part of our country in 1848 by Mexico, coincidental with the discovery of gold, was the real beginning of the area being discussed, and it was a scant thirty-five years later that the first surgeon, Harry Mitchell Sherman, arrived. He had trained in New York under the elder Sayre and, doubtless inspired by him from the beginning, had developed a special interest in children's deformities. One wonders what circumstances motivated this remarkable individual's pioneering in the near wilderness in which San Francisco existed at that time.

Less than 1 per cent. of the population of our entire country was located there at that time, according to the census of 1850. Fifty years later, the 200,000 population had become 4,000,000, and, in 1950, the next half-century mark, it had become nearly 20,000,000 or 12 per cent. of the population of the entire country. This was an area, as stated before, which comprised about 30 per cent. of the total. During these last five years, further remarkable increases have been recorded, particularly around Los Angeles. It is hardly believable, and it unquestionably represents one of the most remarkable increments in population ever recorded. The completion of the transcontinental railroad in 1869 constitutes the third specific factor, but unquestionably the climate has been the major developmental factor.

The coincidence of this tremendous territorial development and increase in population with the progress of medical knowledge, including that of our own specialty, is most fascinating. Modern surgery, made possible after the pre-Listerian era, allowed us to develop into a real surgical specialty, so much so that we are beginning to wonder if we have not gone too far in that direction. Our controversy on the scope of the field of physical medicine should never have been allowed to occur and resulted from the overemphasis on surgery.

Barry Wood, Professor of Medicine at the University of Washington in St. Louis, in his brief monograph "Medical Progress since 1900" outlines remarkably well what has happened. Average longevity, for instance, has increased from fifty to sixty-seven years. If one includes the development of asepsis and anaesthesia, which immediately preceded the turn of this present century, more progress has been made in medicine in this last fifty years than in all previous time.

FIG. 1

Harry M. Sherman
Elected 1889; Died 1921

Wood emphasizes the recognition of the value of the Flexnor report, "Medical Education in the United States and Canada", as perhaps the most important advance. This report, as you know, discussed the state of medical education in the early part of this century (1910) and called attention to the crying need of increased facilities in the future. You will note, as I develop this subject, how important this appreciation has been as regards the establishment of hospitals and training centers the country over, particularly in the West, where precedent and prejudice have not taken such a firm hold. It changed the attitude of the practising physician toward medicine as a science and, even more so, that of the orthopaedist. My immediate predecessor, Dr. A. R. Shands, Jr., last year devoted his Presidential Address largely to this.

Research has been placed in its proper position, and it is difficult to envisage what advances we have to look forward to in the future. Malignancy, cardiovascular problems, skeletal and neurological degenerative changes, and further protection against specific infectious diseases are fields in which much remains to be discovered. Just this last year one more objective was apparently accomplished, which has a good deal to do with our own specialty. For years in checking admission diagnoses, I have found that one-third have been associated with anterior poliomyelitis. Many of our children's hospitals are now having a hard time keeping in sound financial condition thanks to these advances. The waiting lists in our Shriners' Hospitals are becoming shorter. There are just not so many sick children. We now have more time to give better treatment and more money to give researchers and will thus still further deplete hospital censuses.

Before taking up the development of medical facilities, both for the care of the sick and for education, it behooves me to name some of the pioneers in orthopaedic surgery in the Far West who have played a major part in the development of the specialty there. With the increase in population in this early wilderness, there must come pioneer physicians to care for the incapacitated. First must come the general practitioner, then the specialist.

The first real orthopaedic pioneer, unquestionably, was Harry Mitchell Sherman, a native of Rhode Island, who first came to San Francisco in 1885, having been graduated from the College of Physicians and Surgeons at Columbia University five years previously. He did general surgery at the start, but from the beginning, as stated before, he

FIG. 2
George B. Packard
Elected 1887; Died 1928

FIG. 3
James Thomas Watkins
Elected 1907; Died 1934

had a leaning toward orthopaedic problems. Feeling the need of further training, he went abroad for a rather extensive period of time in 1896, and on his return was appointed to the newly established Chair of Orthopaedic Surgery at the University of California. As he had considerable a l-ministrative ability, he became, in a few years' time head of the Department of Surgery and served until 1912. After that, he devoted all of his time to orthopaedics, until his death in 1921.

This pattern, followed by Sherman, characterized the career of the early orthopaedic pioneers who came west before residencies and formal training programs had been established as we know them now. These men acquired their degrees in Eastern schools and then completed their education in Europe.

This pattern, however, was not followed so closely by George B. Packard, our second pioneer, who was an original member of The American Orthopaedic Association. After receiving his orthopaedic training under the elder Sayre in New York, he started practising in Hartford until his health broke and he was forced to go west without a European background (1889). His subsequent recovery and success in his specialty in Denver eminently justified this decision and he became in Colorado much more than an orthopaedic surgeon. He was responsible largely for the organization of the Children's Hospital in Denver in the early days, and headed the Department of Orthopaedics in the school which was later to become the University of Colorado Medical School. His orthopaedic activity extended over a period of nearly forty years. His son is continuing his practice in Denver.

The third prominent orthopaedic pioneer was James Thomas Watkins, who followed closely in the footsteps of Sherman, whose associate he be-

came in 1902. He also contributed tremendously to the development of orthopaedics in San Francisco and the Bay area.

It was Watkins, instigated in all probability by his chief, as Sherman's health was failing, who called together a group of orthopaedists and formed the Pacific Coast Orthopaedic Association in 1920. Thirteen years later he was the chief figure in organizing the Western Orthopedic Association (1932) in order to include more territory. The Pacific Coast Orthopaedic Association actually started as the orthopaedic section of the California Medical Association. It really only had two chapters, however, one in San Francisco and the other in Los Angeles. These were called the San Francisco and Los Angeles Orthopaedic Clubs and met each year in alternate cities. During that period the Northwestern, Southwestern, and Intermountain Clubs were being formed; it was the logical course of events to have these four groups combine to form the Western Orthopedic Association which has been flourishing ever since, except during the war years when meetings were not held.

FIG. 4

Charles F. Eikenbary
Elected 1916; Died 1933

Watkins was elected a member of The American Orthopaedic Association in 1907 and was President the year the Annual Meeting was held in Yosemite Valley. The only other meeting this organization has held in the Far West was in 1949, when we met at Colorado Springs and with Robert W. Johnson, Jr., as President. We really should have met this year at Banff instead of next year, but with meetings of the American Medical Association and the Academy in the West, it seemed wiser to meet in the East in 1955. With continued improved transportation, let us hope, before too long, that we shall meet in Honolulu where the Western Orthopedic Association is convening this November.

These three men, Sherman, Packard, and Watkins, are really the three pioneers in the West; they have contributed tremendously in both a material and an educational way to our specialty in this fabulous territory. Their careers adequately explain how in San Francisco such an early start was made in our specialty.

The next group was headed by Fred J. Fassett who settled in Seattle in 1907. After being graduated from Harvard Medical School, he went to England with the Goldthwait Unit during World War I. He served in this group under Sir Robert Jones in a most creditable way. On his return to Seattle, he was far from well and never did get into his regular swing; he was assisted during that difficult period of his life by Hulett J. Wycoff. He lived until 1926, dying in his fifty-seventh year. He was a practising osteopath before he became dissatisfied and went to medical school. He became a member of The American Orthopaedic Association in 1917, just before he went abroad with Goldthwait.

Another pioneer, somewhat along Fassett's lines, W. W. Richardson, settled in Los Angeles in the very early part of the century. Steele F. Stewart, my contemporary in Honolulu, has told me much about him, saying that he had a wide local reputation and was extremely well thought of. He died in 1924 and never was a member of our Association,

FIG. 5
Richard B. Dillehunt
Elected 1934; Died 1953

FIG. 6
Walter Isaac Baldwin
Elected 1923; Died 1936

but he was a Fellow of the American College of Surgeons. With his unquestionable skill, he established the inclusion of fractures within the domain of the orthopaedic surgeon in the West, almost from the start.

Charles L. Lowman started orthopaedic practice in Los Angeles in 1909 after a Boston and a European training. He founded the Los Angeles Orthopaedic Hospital in 1922. He was followed in about ten years by John C. Wilson. Wilson, the first Massachusetts General Hospital Ward I graduate to go West, was President of the Academy in 1939, the first Far Westerner to hold that Office.

Charles F. Eikenbary settled in Spokane in 1907, having been trained by Ridlon in Chicago and Whitman in New York. After World War I, in which he played an active part in many offensives on the Western Front, he returned to Spokane in 1919; and, in 1923, he became the Chief Surgeon of the newly organized Shriners' Hospital. He moved to Seattle in 1926 to head the Orthopaedic Department of the University of Washington Medical School. It was in this teaching position, and as Chief of Staff of the Children's Orthopaedic Hospital, that he accomplished his most outstanding work. He died at the height of his career in 1934.

Richard B. Dillehunt, our next pioneer, a native of Illinois, and another Chicago-trained man, started as Professor of Anatomy, in 1912, at the University of Oregon in Portland and became Chief Surgeon of the Shriners' Hospital there when it was started in 1923. He resigned because of poor health in 1944. He died just two years ago. Leo S. Lucas succeeded him. Dillehunt and I were elected to membership in The American Orthopaedic Association in 1934, twenty-one years ago, and I remember how we congratulated each other on our success after previous failures.

The picture I have of him, which is none too good, was taken while he was telling a story—and how he could tell them—at the Shriners' Hospital Chief Surgeon's meeting in St. Louis in 1927.

Walter I. Baldwin, a native Californian, was one of the first Eastern-trained men to have graduated from a western medical school, the University of California. On his return from his service at the Massachusetts General Hospital on Ward I under Brackett, in 1913, he joined the faculty of his Alma Mater and, after serving in World War I, was the first Shriners' Hospital surgeon in San Francisco. He only served, however, four years until his untimely death in 1927. He was elected a member of The American Orthopaedic Association in 1923, being one of the very youngest members ever selected.

Hulett J. Wycoff, a Chicago-trained surgeon who was associated with Fassett and Eikenbary in Seattle, was elected to our membership in 1932. He made valuable contributions to the knowledge of cerebral palsy and died prematurely in 1946.

FIG. 7
Rafe Nelson Hatt
Elected 1941; Died 1949

Still another early orthopaedic surgeon, comparable chronologically to Fassett and Richardson, was Richard Rich who was trained under Rugh in Philadelphia and settled in Tacoma in 1907 after a period of study in Berlin and Vienna. He was not a member of The American Orthopaedic Association, or of the American College of Surgeons. I cannot obtain any other information concerning him except that he was considered an outstanding orthopaedic surgeon in the Tacoma area in the early days of the century. According to information obtained from the nearby city of Seattle, he trained many of the present orthopaedic surgeons in Seattle.

One more real pioneer I shall mention in this group is R. Nelson Hatt, who was the first surgeon of the Shriners' Hospital in Honolulu, and really did break the ground in 1922 for that Unit in the little old shack behind the Children's Kauikeolani Hospital. He was a native of Maine, who also had received his training at the Massachusetts General Hospital on Ward I, and after two years in Hawaii, he was appointed Chief Surgeon of the Shriners' Hospital in Springfield, Massachusetts. After leaving Hawaii, he served in Springfield until he went overseas in World War II, after which he returned to Hawaii where he remained until his tragic death in 1949. As you know, I was intimately acquainted with him and succeeded him on two occasions in Hawaii. He did little writing, but his thinking was sound and those who were fortunate enough to come under his tutelage will never forget his kindly instruction. By his friendliness and skill, although, of course, he was far different in appearance, he reminded me of Sir Robert Jones. He was elected to membership in 1941.

INSTITUTIONS

The first strictly orthopaedic hospital started in the West was the Children's Hospital in Seattle, founded in 1907, although the earliest institution designed largely for the care of crippled children was the Children's Hospital in San Francisco, founded in 1875, prior even to Sherman's arrival.

The Children's Hospital in Denver, founded largely by Dr. Packard, was not restricted to orthopaedic cases, although Packard was its head. The Hospital in Los Angeles, which Charles L. Lowman was instrumental in starting, was begun in 1922, and was a restricted orthopaedic institution. It began just before the Shriners' Hospital movement got under way. Many other accredited orthopaedic services, of course, have developed since those mentioned, and their organizers deserve great credit for their labors.

A tremendous boost in orthopaedic facilities the country over and especially in this area was made when the Shriners' Hospital program, conceived at the Shrine Imperial Council in Portland, Oregon, in 1920, was begun in 1923. It is significant that this philanthropic project was initiated in the West and that the second Shriners' Hospital to open its doors was in Honolulu. In our area, three hospitals of fifty beds each, exclusively devoted to orthopaedic surgery, and two smaller so-called mobile ones of twenty-eight beds went into commission in the years 1922, 1923, and 1924. The chief surgeons were selected by an advisory board of eminent orthopaedists with whom we are all acquainted. A sixth Shriners' Hospital in the Far West opened in Los Angeles three years ago.

Your President has been identified with this movement for over thirty years and is too close to pass unbiased judgment on the place that these hospitals, their teaching, and their research possibilities take in orthopaedic surgery. While it is my opinion that full advantage has not been taken of correlating this tremendous mass of clinical material, many invaluable contributions have emanated from these institutions. The future of these hospitals appears secure, as the Shrine Hospital movement is fast approaching the $100,000,000 mark. At least one of the hospitals in the western area is already fully endowed.

The hospital in Mexico City, headed by Juan Farrill, has been in operation for six years. With this there are seventeen in all. Six of them are in our territory comprising about one third of the whole United States.

As regards the increase in Diplomates of the American Board of Orthopaedic Surgery, the last roster (1954) shows that the West has more than added its proportionate share to the total, which is now over 2,500.

While the Academy has elected only two Presidents from this area, our Association has chosen five.

Largely as a result of the Flexnor report, of the twenty-five original medical schools there are nine survivors, five of them being in California. In the entire United States there are now eighty-seven accredited medical schools, while there have been, at one time or another, 371, as given in the 1950 American Medical Association Directory, a mortality over the country of 75 per cent. The figure in the West is considerably below this—64 per cent.

RESIDENCIES

Dr. Arthur N. Springall, Assistant Director of the Council of Medical Education and Hospitals, last fall reported that two of the original eleven accredited orthopaedic teaching services over the entire country were located in this area, namely, the San Francisco Shriners' Hospital and the Portland Shriners' Hospital. This first group of eleven were accredited in February 1927.

The Orthopaedic Hospital School in Los Angeles was next in 1932. Eight more were accredited in the 1930's, twenty-three in the 1940's, and three since 1950, thirty-seven in all. (Our Hospital in Honolulu was accredited in 1947 through the efforts of Dr. Hatt.)

In the report of last fall, there were, over the entire country, 269 approved residencies, including forty-three in Federal institutions.

While, according to the 1950 census, 12.5 per cent. of the population was in the Far West, 13.5 per cent. of the residencies were located in that area.

The purpose of this paper has been to call attention to the development of our

specialty in an area which has been subjected to tremendous stresses and strains. Valiant work has been accomplished by our two organizations, the senior one being the balance wheel and the more robust junior organization furnishing the major portion of the motor power, so necessary in handling such large population areas. We must ever be mindful of this balance and of various innate disturbing tendencies.

While I realize there must be many errors and omissions in this brief account, it may serve as a stimulus for other historical efforts. It is good once in a while to take stock of our present situation and to pay homage to those who have beaten the path before us and have made easier our tasks. We have made a start during these last fifty years and it is now up to our younger members to carry the torch and to add their contributions to what has been so gloriously accomplished by our predecessors.

THE AMERICAN ORTHOPAEDIC ASSOCIATION

Annual Meeting 1955

(Continued from page 1100)

The organization is a tribute to Mr. Gissane, a man who emphasizes the soft-tissue treatment in fractures. He feels that wrong exposure, not open reduction, delays fracture healing; he always approaches a fracture through the side in which soft tissues are already torn by trauma.

He emphasizes the role of the anterior tibiofibular ligament in fractures of the malleolus and fixes the fibula to the tibia with a screw.

Bone grafts are used to repair irreparable ligamentous damage as in fractures of the spine. In tibial transverse fractures in which there are no soft tissues intact (no hinge) early bone-grafting is done.

In fractures that are seen late (that is, after twenty-four hours) none of the principles of soft-tissue treatment are felt to be applicable, and in general the fractures are treated conservatively.

An active member of the team, Mr. Ruscoe Clark, has extensively studied blood loss in closed as well as open injuries. The limb is placed in a polyethylene bag on entry to trap blood loss. The hemoglobin and the hematocrit are closely followed. The injured thigh is measured at successive intervals from the groin to the knee and the calf volume is determined by water displacement. At operation the swabs are weighed and blood volume studies are done in which radio-active phosphorus and chromium are used. The rate of disappearance of transfused cells and balance studies have also been used. The patient returns after recovery for so-called normal volume studies. The methods are applied at various stages in the patient's illness.

On the basis of these studies, it is felt that blood loss in general is underestimated. Swelling within one hour of injury was felt to be due to whole blood. By wrapping a liter volume of felt about the thigh, it has been demonstrated quite conclusively how a liter of blood and more can be hidden in the tissues. Replacement of all blood lost results in reduction of uncontrolled sepsis and in improved and rapid convalescence. Anaemia did not occur and plasma volume was not increased. They did not see retention of sodium and water in patients in whom transfusion was adequate. In those in whom it was inadequate there was release of potassium and then retention. Anuria in the patient with large early transfusions was a rarity. The average blood loss in a closed femoral fracture was felt to be one to two liters, in a pelvic fracture, two to three liters; if operation was performed as well, the blood loss could equal the total blood volume.

Although there were many outstanding centers seen, this details some of the highlights from a brief visit to one of them. When multiplied a thousandfold, this will give one an idea of the maturing benefits of the trip which we are very grateful to you for having had.

Dr. J. Leonard Goldner, Durham, North Carolina.

Mr. President, Members of The American Orthopaedic Association and guests: We have decided to talk in alphabetical order since there is no protocol in our group. I must express my appreciation to The American Orthopaedic Association for the privilege of being able to make this tour. I will say again, as Dr. Ferguson has said, that the welcome and hospitality afforded us in Great Britain was exceedingly fine and I am certain that the friendships the members of our group made with the British, as well as with each other, will last us throughout our lifetimes. This has been one of the finest experiences of my career.

As soon as we arrived in Great Britain, we started talking to the physicians, and the first question following the introductory formalities, was, "How do you like the Health Service?" The answers varied from a very large loud blast to a very weak squeak, and the comments seemed to depend upon the age of the doctor, his previous experience, his specialty, the sort of life he wanted to lead, and the nature of his education. The response was not stereotyped. I received some general impressions, however, and made some interpretations of my own which will be presented briefly. The Health Service has been a natural outgrowth of the changing economy of Great Britain during the last fifty to seventy-five years. Medicine is actually dependent on the economy of the country and in some respects has a parasitic existence. As the economy goes, so will medicine have to follow; and, with the loss of growth and expansion, war, decrease in trade, and dependence on imports, British medicine has had to follow the economic trend of the country. The income of the average individual is low, the standard of living, compared with that of the working man in this country, is much less. After World War II, very few persons could afford even short periods of hospitalization with physicians' fees on a private basis, particularly since there was no adequate private insurance program available. Large segments of the population were necessarily public patients and were already treated as such in the existing Panel System, whereby they received free care from the doctor assigned to them. The specialists, however, were not included in the program and they gave their service on the public wards. With the efforts of the Labour Party and under the instigation of Mr. Bevan, the whole medical domain was socialized, without compromise, in 1947. This included hospitals, doctors, nurses, technicians, vocational schools, drugs, patients, braces, and provision for the family needs of the patient. The people had already become accustomed to rationing and regulation, and this was no particular change for them. The doctors were given a plan on a "take it or leave it" basis, without bargaining or compromise, and most of them have taken it philosophically. They believed that some sort of socialized medicine for their country was inevitable and they accepted this plan with the idea of improving it as much as possible in the future. In this respect the well known professors, the men who are holding the responsible medical positions throughout Britain, accept positions on local or regional governing boards in order to influence policy.

From the patient's standpoint, the care of the large "charity" group has been improved. Attention to the care of the upper group, the so-called private patient, has diminished. The doctor-patient relationship has suffered somewhat, but the physicians and orthopaedic surgeons do not put a great deal of stress on this. Medical attention is available to everyone through the plan, but obviously the majority of the patients have no choice in the selection of their physicians. About 10 per cent. of the population is in the private group, and by paying additional fees and an additional hospital charge, they can maintain a private status for themselves.

The majority of the orthopaedic surgeons have a contract with the government for 80 per cent. of their working week, but reserve the other 20 per cent. for private patients. In that way, they maintain a remnant of "independence" and can still feel that they have some control over their professional activities. Furthermore, they are allowed certain income tax deduction if they maintain the private practice; this deduction is important when one considers the high rate of income tax in Great Britain.

It should be emphasized that there was no indication of government interference with the orthopaedic surgeon in his daily relationship with the patient, although indirectly there was considerable interference because a young orthopaedic surgeon who has just completed his training cannot go into the practice of orthopaedics until a position becomes open in a community. This implies that the regional board must decide if an orthopaedic surgeon is necessary in a given community, whether adequate beds are available for patients under his care and whether he is the surgeon for the community, if a position opens. As a result of this, a senior registrar (resident) may wait for several years after completing his training before he actually practices orthopaedics. The alternative is general practice or immigration to Australia, New Zealand, or Canada. During the past five years the economy has improved and the sale of health insurance has increased tremendously. This implies that patients do want more private attention, that they are asking for it, and that they are probably getting it. One big problem is the lack of adequate hospital beds to handle the great influx of patients. The physicians are seeing more patients with minor complaints who demand hospitalization. The average orthopaedic surgeon may rush through an examination of fifty or sixty patients in the morning and not be able to give many of them the attention that seems necessary. The general practitioner can get by without spending much time examining a back. He can merely refer the patient to the specialist because the service is free and there is no need for him to try conservative therapy at home. Furthermore, the patient can demand roentgenographic examination, physical therapy, and specialist consultation, and a general practitioner is only too glad to refer the patient. If the specialist or the practitioner is not careful in his attitude and routine with the patient, he is liable to suit, since the patient can get free legal aid from the government. The answer is not more doctors, but fewer persons who are not really sick. Nevertheless, I will say that the high integrity of the orthopaedic surgeons and other physicians in Great Britain is allowing this system to function, and I believe that as time goes by, the medical profession will help the government to form a satisfactory medical plan. The situation may finally adjust itself in Great Britain, but it is certainly not necessary or desirable in this country. Medicine must take the lead and provide for certain inequities and deficiencies in patient care before government agencies take over this responsibility.

Dr. Charles F. Gregory, Indianapolis, Indiana.

Mr. Chairman and Members: My predecessors have expressed my feelings about the value of the exchange tour quite accurately and I should simply like to add my thanks to theirs. I am to cover something of the research which we encountered in Great Britain and quite obviously at this time can do little with it. May I comment on some of the things which we did see.

Most of the centers seemed to have extensive clinical research programs underway. Certain features in the British medical system tend to enhance and facilitate clinical research because of the following points: First, hospitals are staffed for the most part by full-time men. Second, each hospital serves a regional area and is therefore assured of a relatively constant flow of clinical material. Third, they are not hampered by restricted hospitalization in order to relieve economic pressure upon the patient. As a result, most of their clinical research projects can be nicely scheduled and the schedule adhered to. It is my opinion that such facilities, and the advantage of a continuous and long-range follow-up will permit the accumulation of a great deal of very valuable and reliably accurate information.

As an example, may I point out the approach to congenital dislocation of the hip as we saw it at the Wingfield-Morris Hospital in Oxford under Prof. Trueta and his group. At that Center cases of congenital dislocation of the hip are treated primarily by two men, Mr. Scott and Mr. Summer. In the past four or five years they have accumulated a series of fifty cases. The remarkable feature of this series lies in the fact that the program of treatment in each case has been the same. The treatment, as employed there, consists in a closed reduction accomplished slowly on a Wingfield-Morris frame. X-rays are made at weekly intervals and at the end of the fourth week an arthrogram is made. If there is any indication of inadequacy of reduction due to an inverted limbus, a limbectomy is performed at once. The dislocation is reduced and the hip is placed in internal rotation and so held in a spica cast. At the end of an additional four weeks, a derotation osteotomy is done at the subtrochanteric level. Upon union of this osteotomy, usually after eight weeks, the child is removed from the cast and is permitted full activity with no splinting at night and with no guards of any kind.

We were shown fifty cases so treated. We saw some of the patients and most of the x-rays which had been made upon them. We saw the most recent x-ray in all fifty cases.

Rather than impart to you my own impressions of the value of this method of treatment, I think I should say that it is too early to draw conclusions from this study. I do wish to say that if this series is followed up adequately and is reported, we will know pretty much what can be expected from treating congenital dislocation of the hip by this particular method, for it is a relatively pure series.

We did encounter some basic science research of remarkable interest in Edinburgh performed by Mr. Robert Duthie. This work has been reported in *The Journal of Bone and Joint Surgery*, **37-B**: 304, 1955. This investigator had utilized radio-active sulphur in the study of cartilage as it is involved in the growth and repair of bone. Because it has been reported, I shall not elaborate upon it.

In Liverpool, Mr. H. O. Williams presented to us electron-microscopic studies of the mineral element in Paget's disease of bone. Taking as his cue for the normal the work of Robinson, from this country, he has discovered that the mineral content of bone from Paget's disease is remarkable in three ways: first, the hydroxyapatite lattice work which is the basic structure in the mineral component of bone, is not to be found. Second, in the irregular crystalline structure which has replaced it, there is present an abnormal amount of sodium. Third, considerable quantities of fluorine were detected in the crystalline fraction study. He hopes to conduct additional studies on the collagen and protein elements of bone involved in Paget's disease in order to complete the picture. It is worth while, I believe to point out the curious correlation between the high concentration of fluorine in bone from Paget's disease and the high concentration of fluorine in the bones of certain persons and animals from Deaf Smith County, Texas. In each instance one of the characteristics seems to be an unusual hardness and strength. It would seem to me that these coincidences open a rather remarkable vista for further investigation.

Many other interesting research projects were shown to us including basic science research at the Nuffield Institute for Orthopaedics at Oxford. These covered such subjects as the circulation in the femoral head and neck in health and disease, methods for the stimulation of longitudinal bone growth, and normal swallowing mechanisms as compared with abnormalities in swallowing as encountered in poliomyelitis. Among the most interesting were the studies on the pathology in the spinal cord in acute, convalescent, and healed anterior poliomyelitis done at the Stanmore Division of the Royal National Orthopaedic Hospital. Clinical research in the business of peripheral-nerve injuries was shown to us at the London Division of the Royal National Orthopaedic Hospital. The culmination of that work has had its expression recently in a new book edited by Mr. H. J. Seddon.

All in all, it was my impression that this research, both clinical and basic in nature, was interesting, timely, and fruitful.

Dr. Daniel C. Riordan, New Orleans, Louisiana.

I also wish to thank this Association for the privilege of being allowed to take this wonderful tour. One of the things in which I was most interested, since all of us are operating surgeons, was anaesthesia. I want

to talk about just one type of anaesthesia that we saw used in Great Britain because it was new to me — hypotensive anaesthesia. We saw this used in a number of hospitals, chiefly for procedures on the shoulder and the hip. I understand that it can also be used for procedures on the back. With the use of this type of anaesthesia the patient can be positioned so that the part to be operated upon is highest and the other parts are dependent and the blood is pooled there. The patients are seen by the anaesthetist before the operation in order that suitable patients may be chosen; those with high blood pressure and with cardiovascular disease obviously are not suitable. The patient is induced usually with sodium pentathol. Intubation is done under such a short-acting muscle relaxent as ascoline or anectine. Nitrous oxide, with trilene or a similar agent to supplement the nitrous oxide, is given. The necessity for a very high oxygen content during the giving of the anaesthesia and the positioning of patient was stressed. By means of the administration of hexamethonium or camphor sulfonate or some similar drug and by the continuing of small amounts of the drug through an intravenous drip over a stated period of time the blood pressure is lowered to the point where there is no bleeding in the operative site. Demerol, in small doses, is used to supplement the analgesia so that much anaesthesia will not be required. The anaesthetist then raises the blood pressure after it had been lowered. One said that the blood pressure should never be lowered much below 80, while another lowered it to 40. This is, of course, systolic pressure. The blood pressure is raised before the surgeon closes the wound in order that any bleeders which have not been tied may now be cared for. Since there was pooling of the blood in the legs, we asked if there had been any increase in thrombophebitis over that expected after normal operative procedures. The incidence of thrombophebitis was not greater than the normal. An occasional hematoma occurred; but the incidence was not greater than that with the usual type of anaesthesia. Death had occurred in some patients and there had been cerebral damage. We do not know what the death rate is; in Edinburgh it was said that in 500 hypertensive anaesthetics for all types of surgery they had had two deaths and there had been some patients in whom some permanent cerebral damage was done as a result of the lowered pressure. Further work still has to be done on this.

In Edinburgh we saw hypothermia being done by three methods: one by means of external cooling of the patient (not very good); another was by means of lowering temperature by drugs affecting the central nervous system; and the last by means of blood-stream cooling. In this method an arterial cannula ran the blood through a silicone-coated tubing ten feet long which was surrounded with ice water. The blood was returned to the patient's veins, the patient's heart being his own pump. The reason I have mentioned this, of course, is that while it is obviously best suited for heart and kidney surgery, it apparently might have some use in orthopaedics in the severely injured patients in whom immediate surgery cannot be done. You all know that, from the experience the doctors in Great Britain have had with people who were badly injured, many toxic reactions had occurred from the products liberated. Apparently, the cooling seems to knock out these enzymes and therefore prevents poisoning.

Once again I wish to thank the Association.

On the evening of the nineteenth the President's Reception was held and the members elected at the 1954 meeting of the Association were presented.

At the Second Executive Session, Dr. Paul C. Colonna, the President for the coming year, was inducted into office. The following officers and members of committees were elected:

Officers

President-Elect: David M. Bosworth, M.D., New York, N. Y.;
Vice-President: Charles R. Rountree, M.D., Oklahoma City, Oklahoma;
Treasurer: Mather Cleveland, M.D., New York, N. Y.;
Secretary: George O. Eaton, M.D., Baltimore, Maryland.

Committee Members

Membership Committee: Robert A. Knight, M.D., Memphis, Tennessee;
Program Committee: Carter R. Rowe, M.D., Boston, Massachusetts.

Representatives on The American Board of Orthopaedic Surgery

Harold A. Sofield, M.D., Oak Park, Illinois;
William M. Roberts, M.D., Gastonia, North Carolina;
George J. Garceau, M.D., Indianapolis, Indiana.

Delegates to the American College of Surgeons

Donald King, M.D., San Francisco, California;
Edwin F. Cave, M.D., Boston, Massachusetts;
George K. Carpenter, M.D., Nashville, Tennessee.

Elected to membership were the following:

Leonard Barnard, M.D., Oakland, California
Charles O. Bechtol, M.D., New Haven, Connecticut
Ernest A. Brav, M.D., Washington, D. C.
Leonard F. Bush, M.D., Danville, Pennsylvania
Eldon G. Chuinard, M.D., Portland, Oregon

Harold E. Crowe, M.D., Los Angeles, California
Charles H. Frantz, M.D., Grand Rapids, Michigan
Charles H. Herndon, M.D., Cleveland, Ohio
John F. LeCocq, M.D., Seattle, Washington
Paul R. Lipscomb, M.D., Rochester, Minnesota
Samuel S. Mathews, M.D., Beverly Hills, California
Wilbert H. McGaw, M.D., Cleveland, Ohio
Robert D. Ray, M.D., Seattle, Washington
O. Sherwin Staples, M.D., Hanover, New Hampshire

The next Annual Meeting of The American Orthopaedic Association will be held at the Banff Springs Hotel, Banff, Alberta, Canada, from June 20 to 23, 1956.

VIRGINIA ORTHOPEDIC SOCIETY

As Reported by William Minor Deyerle, M.D., *Secretary*, Richmond, Virginia

The Annual Scientific Meeting of the Virginia Orthopedic Society was held on April 22 and 23, 1955, at the General Hospital in Winchester, Virginia, under the presidency of Dr. Allen Ferry. The Scientific Program had been arranged by Dr. Bradford S. Bennett, and reports were submitted by Dr. William M. Deyerle, *Secretary-Treasurer*.

Experiences with the Lottes Nail. Dr. Joseph L. Platt [1] presented six cases of compound fracture of the tibia, in which he had used a Lottes nail. It was used to gain a more perfect immobilization in order to decrease trauma and, thereby, to decrease the incidence of oedema and infection. In one patient, a low-grade infection developed, but this was eventually brought under control. In another, union was secured at the end of one year, with no infection. In a third union was progressing but the fracture had not completely healed at the time of the presentation. In another union occurred slowly. This was not completely satisfactory, but union was apparently going to occur. There was one case of an old non-union in which the fibula had united. In this case the fibula was resected to relieve it of its distracting force. Through the same incision the fibula was used as a bone graft for the non-union. Union occurred after one year. In one patient the pin went into the ankle joint, but in view of the patient's age, it was not removed. Non-union developed, and the same approach was again used, the fibula being resected and used as a graft. Union appeared to be progressing satisfactorily at that time. In one other patient, operated upon primarily, union with no infection appeared to be progressing. He felt that if the fibula unites before the tibia, it acts as a distracting force and probably should, therefore, be osteotomized. Most of these fractures had been immobilized in plaster and the patient was walking in two to six weeks. He continued immobilization in a toe-to-groin cast until such time as union appeared sufficient to render the support of the cast unnecessary.

The general discussion of this paper was very favorable, as it was felt that the use of the Lottes nail in this situation probably decreases the chances of infection and non-union, and also decreases the danger of further disturbance to circulation.

Anaesthesia in Orthopaedic Surgery. Dr. Robert Morrison [2] gave an excellent discussion of the various types of anaesthesia and their application to orthopaedic surgery. He felt that each individual patient presented a definite problem from the standpoint of anaesthesia that should be solved on a basis of the individual requirements. In spinal anaesthesia, he mentioned the use of adrenalin in the spinal fluid to double the time of the anaesthesia.

In the discussion that followed, it was brought out that many of the cases of cardiac arrest could probably be prevented by careful attention to the amount of carbon dioxide accumulating in the blood and the lack of oxygen available. It was also pointed out that many of the ill effects resulting from spinal anaesthesia were due to improper handling of the solutions to be used, or a failure to maintain carefully these solutions.

Pigmented Villonodular Synovitis. Dr. Bradford S. Bennett [3] presented a case of an osteochondroma of the knee with a bursa formation. This was of a circumscribed type and, after complete synovectomy, appeared to be arrested. The second case was a diffused pigmented villonodular synovitis, which was invading the bone. Dr. Granville Bennett suggested that this type be called "benign synovioma". It was of inter-

[1] 301 Rivermont Avenue, Lynchburg, Virginia.
[2] Lynchburg, Virginia.
[3] 214 West Boscawen Street, Winchester, Virginia.

est that the synovitis had occurred in an old recurrent dislocation of the shoulder. The slides of this case were sent around for consultation and, although there were occasional mitotic figures, there was no definite evidence of malignancy discovered by the examining pathologists. One year later there was no evidence of recurrence of the disease locally.

Panel Discussion on Matters Relative to the Industrial Commission of Virginia as They Affect Orthopaedic Surgery. The discussion of matters relative to the Industrial Commission of Virginia was opened by a brief paper by DR. WILLIAM M. DEYERLE [4] entitled, "Medical Reports in Industrial Cases". This paper went into detail concerning the mechanics of reporting in an industrial case. The general principles outlined were for a careful, accurate history taken on the first visit, as this is the most accurate information that can be obtained. The later recollections of on-the-job injuries tend to be less accurate; however, they should be written down and the patient should be quoted verbatim. The date on which he reports these facts should be given, as well as the date on which he states that the injury occurred. Careful industrial reports and accurate, sensible estimates of periods of temporary and permanent disability reflect very definitely on the physician and make for easier handling of all industrial cases. A careful wording of the reports with reference to the patient's ability to return to his work and the type of work that he may perform may prevent many of the complications of labor relations and the labor-medical relations that sometimes occur.

This was followed by a general discussion from the floor. Dr. Deyerle acted as moderator; and MR. MARVIN NUCKOLS of the Industrial Commission in Richmond, Virginia, DR. LEVI HULLEY, Medical Advisor to the Industrial Commission, and DR. ROY HOOVER of Roanoke, Virginia, attempted to answer various questions from the floor. This brought on a lively and stimulating discussion.

A Method of Spine Fusion with Analysis of Results to Date. Dr. BENJAMIN R. WILTBERGER [5].

This was presented as a Faulkner Memorial Lecture in honor of the late Dr. Donald Faulkner. Dr. Wiltberger presented a study of his interbody fusion and illustrated the impressive operative procedure with excellent follow-up x-rays. He had a large series of cases and had the actual x-rays of each case available for inspection. These showed a high percentage of apparently solid spine fusions.

This presentation was well received and was followed by a round-table discussion of general cases with Dr. Wiltberger acting as moderator.

[4] 2222 Monument Avenue, Richmond 20, Virginia.
[5] 350 East Broad Street, Columbus 15, Ohio.

GORDON RESEARCH CONFERENCE ON THE STRUCTURE, CHEMISTRY, AND PHYSIOLOGY OF BONES AND TEETH

MERIDEN, NEW HAMPSHIRE

August 1 to 5, 1955

MONDAY A.M., *Collagen*

F. O. Schmitt (Massachusetts Institute of Technology), *Chairman.*

Some Aspects of the Chemistry of Collagen, J. H. Highberger (United Shoe Machinery Corporation);

Enzymic Degradation of Collagen, J. MacLennan (Columbia University);

Collagen Formation in Tissue Culture with Special Reference to the Role of Ascorbic Acid, B. S. Gould and J. F. Woessner (Massachusetts Institute of Technology) and H. M. Goldman (Beth Israel Hospital, Boston).

MONDAY P.M., *Submicroscopic Structure of Bones and Teeth*

Robert A. Robinson (Johns Hopkins), *Chairman.*

Arne Engström (Karolinska Institutet, Stockholm, Sweden), *Speaker.*

TUESDAY A.M., *Nature and Elaboration of Ground Substance*

D. Dziewiatkowski (Rockefeller Institute), *Chairman.*

Utilization of C^{14}-Bicarbonate in Studies of the Formation and Fate of Organic Matrix of Bone and Dentin, R. Greulich (University of California, Los Angeles);

Chromatographic Characterization of the Sulphate-Containing Components in Bone of Suckling Rats of Intervals of Time Following the Administration of S^{35}-Sulphate, N. Di Ferrante, F. Bronner, and D. Dziewiatkowski (Rockefeller Institute);

Histochemical and Allied Radioisotope (S^{35}) Studies of the Mucopolysaccharides of Calcifiable Rachitic Epiphyseal Cartilage, A. Hirschman (State University of New York).

TUESDAY P.M., *The Bone Matrix Structure in the Adult*
J. Arnold (University of Utah), *Chairman.*
Pierre Lacroix (University of Louvain, Louvain, Belgium), *Speaker.*

WEDNESDAY A.M., *Skeletal Dynamics* I
F. Bronner (Rockefeller Institute), *Chairman.*
Accretion, Resorption, and Exchange Reactions of the Bone Salt, A. Carlsson (University of Lund, Lund, Sweden);
Isotopes as a Diagnostic Tool in Metabolic Bone Disorders, G. C. H. Bauer (University of Lund, Lund, Sweden);
Dynamics of Calcium and Strontium Metabolism in Man, H. Spencer (Montefiore Hospital, New York, N. Y.).

WEDNESDAY P.M., *Skeletal Dynamics* II
C. L. Comar (Oak Ridge Institute of Nuclear Studies), *Chairman.*
Radium as an Indicator of Skeletal Dynamics, W. P. Norris and T. W. Speckman (Argonne National Laboratory);
Metabolic Comparisons of Strontium and Calcium, N. S. MacDonald (University of California, Los Angeles);
The Relationship Between Skeletal Uptake, Blood Level, and Intestinal Absorption, Using Radio-Active Strontium, L. F. Wolterink (Michigan State College).

THURSDAY A.M., *The Parathyroids.* I. *Chemistry and Physiology*
R. Greep (Harvard School of Dental Medicine), *Chairman.*
Studies in the Bio-Assay and Purification of Parathyroid Hormone, B. M. A. Davies and A. H. Gordon (National Institute for Medical Research, London);
Parathyroid Physiology I, R. V. Talmage (Rice Institute, Houston, Texas);
Parathyroid Physiology II, F. C. Bartter (National Institute of Health).

THURSDAY P.M., *The Parathyroids.* II. Clinical Aspects
B. Kramer (State University of New York), *Chairman.*
Parathyroid Disease in the Adult, I. Snapper (Beth El Hospital, New York, N. Y.);
Parathyroid Disease in the Infant and Child, L. I. Gardner (State University of New York);
Idiopathic Hypercalcuria, P. H. Henneman (Massachusetts General Hospital, Boston);
Congenital Absence of Parathyroids: Case Report, P. L. Calcagno and C. Whitten (University of Buffalo);
Pseudohypoparathyroidism: Incomplete Form with Metabolic and Follow-up Studies, A Case Report, D. Gribetz (Mt. Sinai Hospital, New York, N. Y.).

FRIDAY A.M., *Recent Studies on Agents Affecting Bone*
E. Shorr (New York Hospital), *Chairman.*
Tracer Studies in Bone with C^{14}-Labeled Estrogen, F. C. McLean (University of Chicago);
Skeletal Lesions Produced by Aminonitriles, L. V. Ponseti (State University of Iowa, Iowa City);
The Metabolic Fate of Radiocalcium in Patients with Thyroid Disease, S. Krane (Massachusetts General Hospital).

CORRECTION

In the closing paragraph of the report of the 1955 Meeting of the Section on Orthopaedic Surgery of the Medical Society of the State of New York there appears an error. The report as submitted was published in the July 1955 issue of *The Journal.* Dr. Frederick L. Liebolt was elected delegate for the Orthopaedic Section instead of Dr. William E. Gazeley. Dr. Liebolt is connected with the Hospital for Special Surgery, New York City.

AMERICAN MEDICAL ASSOCIATION
SECTION ON ORTHOPAEDIC SURGERY

The Annual Meeting of the Section on Orthopaedic Surgery of the American Medical Association was held in Atlantic City on June 7, 8, and 9, 1955. Dr. Jesse T. Nicholson was in the Chair. An unusually good program had been arranged by the Secretary, Dr. Frederick R. Thompson. At the Executive Session following the Scientific Program the following officers were elected for the ensuing year:

Chairman: William T. Green, M.D., Boston, Massachusetts;
Vice-Chairman: Edward L. Compere, M.D., Chicago, Illinois;
Secretary: Frederick R. Thompson, M.D., New York, N. Y.;
Representative to the Scientific Exhibit: J. Vernon Luck, M.D., Los Angeles, California;
Delegate: H. Relton McCarroll, M.D., St. Louis, Missouri;
Alternate Delegate: Robert J. Joplin, M.D., Boston, Massachusetts;
American Board of Orthopaedic Surgery: George W. N. Eggers, M.D., Galveston, Texas, and Edwin F. Cave, M.D., Boston, Massachusetts.

The following are summaries of the papers presented at the Scientific Sessions, as prepared by the Secretary, Dr. Frederick R. Thompson of New York City.

Traumatic Dislocation of the Head of the Radius in Children. Dr. Frank H. Stelling, III [1], and Dr. Richard H. Cote [2] called attention to an infrequent childhood injury that may go unrecognized or be mistaken for a sprained elbow. It is dislocation of the head of the radius without fracture of the ulna. Twelve such dislocations were included in the authors' series: four were treated early, within the first four days, five were seen late and could not be reduced, and three were old paralytic unreduced dislocations. The prompt reduction of the four early dislocations gave excellent results. The authors reported surprisingly good function in the old unreduced dislocations. Although a prominence could be seen and felt on the outer aspect of the elbow, there was usually present full flexion and only about 15 degrees of limitation of extension. Pronation and supination were usually complete. None of the late cases complained of painful elbows. There was no growth disturbance at the elbow or the wrist. Operative treatment in these late cases was unnecessary; the authors felt that removal of the radial head was to be condemned.

Of particular interest was the fact that the dislocation frequently occurred from minor trauma and was not recognized immediately by the physician. None of these twelve dislocations were diagnosed immediately because of the lack of symptoms and the absence of clinical signs of swelling, or other reaction. The condition is a complete dislocation and differs from "nursemaid's elbow" which is thought to be a simple rotatory subluxation unaccompanied by roentgenographic changes. Pathologically, the condition is believed to be a complete tear of the annular ligament with dislocation of the radial head. Most of the dislocations were anterolateral but some were posterolateral; these latter should not be confused with congenital dislocation of the radial head.

Dr. Francis W. Glenn [3], opening the discussion, reported his findings in two additional patients; one of these had been treated late, came to surgery, and considerable bony overgrowth developed about the joint structures.

Dr. John H. Aldes [4] drew attention to the work of Fournier in 1671, who first described the injury as an incomplete dislocation characterized by relaxation of the ligaments, "elongation" of the radius, and a direct separation or diastasis of the radius distally. Eighty years later Duverney (1751) gave a detailed account of two forms of dislocation which he thought to be due to a combination of extension and traction at the wrist. He mentioned as the chief symptom a block to supination of the forearm; reduction had been accomplished by forcible supination, with pressure anteriorly upon the radial head, followed by flexion of the elbow. It is to be noted, however, that in the authors' series of twelve cases the trauma was usually a fall on the outstretched arm or on the elbow itself.

The Importance of Routine Pre-Employment Examination of the Back. Dr. Rex L. Diveley [5] and Dr. Rial R. Oglevie [6] had made a survey covering 6,500 routine pre-employment examinations of the low back. It is estimated that, in the industries in which the studies were made, 50 per cent. of the entire cost of all types of injuries and disabilities are due to low-back trouble. When roentgenograms were made of the low back at the time of the examination, 41 per cent. showed congenital anomalies in the lumbosacral region, 39.9 per cent. presented normal spines, and 6 per cent. showed wear-and-tear changes in the lumbo-

[1] 206 East North Street, Greenville, South Carolina.
[2] Shriners' Hospital for Crippled Children, Greenville, South Carolina.
[3] 168 S.E. First Street, Miami 32, Florida.
[4] 4833 Fountain Avenue, Los Angeles 29, California.
[5] 4312 J. C. Nichols Parkway, Kansas City, Missouri.
[6] Kansas City, Missouri.

sacral joint. On the basis of these examinations, from the roentgenographic findings, and particularly from a history of past low-back trouble, 3.6 per cent. of all applicants were refused employment, but 12.5 per cent. were assigned to limited or specific duty. As each year passes, the number of rejected applicants increases and the number of men with low-back disabilities reporting to sick call has decreased. In the past year, the rejection of applicants for employment rose to 5.5 per cent., while 11.3 per cent. were placed on limited duty. In the larger plant in which the study was made, over a six-year period, only twenty-two low-back injuries were subject for compensation. Six of the men with injury lost no time from work, but the remaining sixteen lost a total of 10,036 man-days. The financial loss to the company was $34,996.99. The accounting department of the plant feels that the cost of preliminary employment examinations is negligible when compared to the dollars and man-days saved to the employer and employee. The suggestion was made that a joint committee of orthopaedic and industrial surgeons be set up to institute and analyze surveys on this subject.

Dr. Leonard T. Peterson [7], in his discussion, quoted a 30.5 per cent. rejection rate in stevedores in a study by Stewart. If the rejection rate is too high, the examination would be unacceptable to labor. If satisfactory criteria can be established, he believed there should be some provision for the placement of the handicapped who otherwise would have difficulty in finding employment.

Dr. Charles Rombold [8], in his discussion, disagreed with the authors that roentgenographic examinations produced a major decrease in the incidence of industrial back cases. In a similar study, he too had noted a dramatic drop in the employer's compensation expenses after the institution of pre-employment examinations. The chief reason for this drop was a well instituted and planned program of teaching the laborers how to lift without injuring the back. This was done by an active campaign of instruction, by lectures, demonstrations, placards, and printed handouts. Careful supervision on the job, correction of poor work habits, and improvement of safety measures, the installation and greater utilization of mechanical equipment, were additional important factors in saving money and man-hours.

Vertebral Osteophytosis: A Clinical Syndrome. Dr. Edgar M. Bick [9] discussed a fairly common pathological finding seen in roentgenograms of the vertebral column, so-called vertebral osteophytes which grow out from the adjacent borders of two vertebrae to form spurs. They are visible usually in lateral roentgenograms. These are true bony overgrowths that may properly be labeled "osteophytes", since they contain trabecular bone structure. They are not an evidence of "rheumatoid" spinal arthritis with which they have been confused in the past. The causative factor is often associated with trauma to the vertebral ligaments or with spontaneous degeneration of, or damage to, the intervertebral discs. They are occasionally seen following compression fractures of the vertebral body. They are, however, primary lesions, not necessarily associated with osseous defects. In general, they are asymptomatic whether primary or secondary. Pathologically, they are osteogenic proliferations occurring within the vertebral ligaments at their insertions into the apophyseal ring of the vertebral bodies. They may vary in size from a few millimeters in length to a large double plaque crossing the intervertebral space. The author believed them to be the characteristic reaction to strain found at the insertion of powerful ligaments into bone, similar to those seen throughout the axial and appendicular skeleton. This similar phenomenon is well recognized along the iliac crests at the femoral adductor tubercle and at the insertion of the long plantar ligament into the calcaneus. They are found more often in the anterior longitudinal ligaments and in the lateral ligaments, but are rarely found in the posterior ligaments. They are rarely seen before the age of forty and are more prone to occur in the short stocky individual. When they produce symptoms, it is because the area becomes inflamed. The inflammatory process is self-limiting and requires only the palliative therapy of bed rest, spinal support, and the local application of heat. The author believed it to be important not to label this condition "spinal arthritis", since such a diagnosis frequently causes the patient to go to unnecessary extremes of worry, financial expense, and medical investigation, when his fears could be dispelled by telling him truthfully that the lesion is of little importance to his future health and activity.

Discussion by Dr. J. Hamilton Allan [10] and Dr. Arthur F. Seifer [11] brought out the fact that osteophytes were rarely seen before the age of thirty-five and that, at the age of forty-five, 83 per cent. of heavy, stocky individuals show them, but only 10 per cent. of the slender type had them. At the age of sixty, these changes were present in many of the slender type. They felt they are the normal result of daily stresses and strains on the body in the upright position, that symptoms could usually be prevented by adherence to the rules of good body mechanics with well balanced spinal muscle tone and disciplined weight control.

Fractures of the Humerus: Ambulatory Traction Technique. Dr. Hira E. Branch [12] indicated that am-

[7] 915 19th Street, N.W., Washington 6, D. C.
[8] 3244 East Douglas, Wichita 8, Kansas.
[9] 30 East 60th Street, New York 22, N. Y.
[10] University of Virginia Hospital, Charlottesville, Virginia.
[11] 3401 North Broad Street, Philadelphia 40, Pennsylvania.
[12] 821 Mott Foundation Building, Flint 3, Michigan.

bulatory traction treatment of humeral fractures enables patients to be treated in the office and frees hospital beds; many patients may continue at partial work; the technique, he felt, was economically sound. Of 187 fractures of the humerus, the vast majority above the level of the humeral condyles could be treated by this method. Plaster slabs are placed on the four sides of the fractured humerus as far as the elbow. A circular forearm cast which has been split is attached by a sling to the neck, so that its weight exerts traction on the humerus. A pillow is then placed in the axilla. He occasionally injected novocain locally into the fracture site for anaesthesia and then reduced the fracture angulation by pressure after the plaster supports had been bandaged to the arm. Occasionally, an extra weight is added to the circular forearm plaster to aid in reduction during the first twenty-four hours. Radial palsy cleared up without surgery. Very few patients had come to surgery unless they were reporting because of non-union. No fracture of the humeral head in his series had come to surgery but three fractures of the shaft had required surgery. Two fractures of the supracondylar area, and 55 per cent. of the fractures through the condyles had required surgery. The incidence of radial palsy in his series had been 17.6 per cent. and the incidence of ulnar palsy had been 3 per cent.; 14.7 per cent. had multiple fractures.

Dr. Charles N. Pease [13] endorsed conservative treatment of these humeral fractures. He believed open reduction and internal fixation far too common, and believed also that exploration of the radial nerve was performed too frequently and too early following paralysis.

Dr. Edward M. Winant [14] agreed that fractures of the upper two-thirds of the humerus rarely required operative intervention unless non-union had occurred. He felt that plaster splints, however, about the upper arm were unnecessary, since the weight of the forearm alone with a wrist sling suspended from the neck was sufficient traction. The weight of gravity was thus used to reduce the fracture. He cautioned against the use of additional weights placed on the forearm in fractures of the surgical neck of the humerus, since a previous report by him and Thompson in 1939 had shown a 20 per cent. incidence of subluxation of the humeral head from the glenoid. This subluxation is visible in roentgenograms made with the patient standing and should not be augmented by further traction upon the forearm. He believed that fractures of the supracondylar region and fractures through the condyles themselves should never be treated in the office alone. He noted that a reduction of a supracondylar fracture was usually not difficult, but maintenance of position was always a difficult problem. Fractures of the lateral humeral condyle, when separated, should always be operated upon and the free fragment replaced surgically, if deformity and impairment of function are to be prevented.

Delayed Closure of Compound Fractures. Dr. Donald T. Imrie [15] pointed out that the surgeon, in evaluating a contaminated compound fracture, must carefully consider the extent of soft-tissue damage, the type and location of the fracture, the locale of the accident, the age and condition of the patient, and the lapse of time since injury. He must consider what facilities are at his disposal from the standpoint of personnel, of anaesthesia, blood, laboratory facilities, operating room facilities, and equipment for fixation, and also his own experience and capabilities. He should never use internal fixation or do a primary closure on a potentially infected fracture. On the other hand, he should not deny his patient the comfort, freedom, and better function to be gained by internal fixation if he can be sure that infection can be controlled and fixation material be well tolerated. Even the experienced surgeon, with superior judgment, cannot know all factors involved, so he tries either to treat the individual with internal fixation and primary closure, or takes the second alternative of avoiding adequate bone contact and leaves the wound open.

Dr. Imrie drew attention to a compromise form of treatment which avoided the inherent dangers of primary closure and, at the same time, prevented secondary contamination—delayed primary closure. This technique stems from the work of Du Mortier who, in 1933, showed the amazing resistance raw tissues build up against infecting organisms through fibroplasia and organization of surface exudates. This barrier develops after the first six hours and reaches a maximum against the spread of infection on the fourth or fifth day, in the case of wounds in the guinea pig. A careful débridement of the wound is advocated after the limb has been washed and shaved. Devitalized and grossly contaminated tissues are excised by sharp dissection wherever possible. Minor bone fragments are discarded *but only if absolutely non-essential for stability or continuity.* A key bone fragment, if contaminated, should be removed from the wound, cleansed thoroughly, and fitted back into place, where it may serve as an autogenous-bone graft. If the fracture site cannot be stabilized without internal fixation, the least amount of metal is chosen that will hold the fragments in place with the aid of a plaster cast. The wound is not closed. The fascial layers are left open, silk wicks are tucked loosely into the deepest corners of the wound, and silk packs are laid in the wound, holding the skin edges apart. Vertical mattress sutures of single filament nylon are placed in the skin so that a second operation for delayed closure would not require anaesthesia. Single knots are tied in these nylon filaments and the wound edges are partially drawn together. After plaster support has been added, the extremity is ele-

[13] 104 South Michigan Avenue, Chicago 3, Illinois.
[14] 115 East 61st Street, New York 21, N. Y.
[15] 900 Crawford Street, Vicksburg, Mississippi.

vated and the usual antibiotics are given. Dr. Imrie was not opposed to solutions of penicillin and streptomycin being injected under the silk packs in the wound. Four to six days later, a window is cut in the plaster cast and the skin edges are drawn together by delayed primary closure. Sixty consecutive compound fractures of long bones had been reviewed in civilian practice; 93 per cent. were found to be satisfactorily healing. Colored slides of the operative technique and slides of roentgenograms were shown to demonstrate the method.

Dr. Clyde W. Dawson [16] felt that the author had answered most of the objections that might arise in the minds of those who prefer, with the immediate débridement, reduction with primary closure or the open treatment as advocated by Orr and by Trueta under adverse conditions. In reviewing his own cases, he felt that many could be treated successfully by complete débridement, fixation, and primary closure. He felt that antibiotics had made this more feasible than it had been in the past. Some few had required drains in the wound, but he had not used this form of delayed secondary closure in civilian cases. He re-emphasized the importance of the length of time which had elapsed following injury before débridement and of the help of a trained anaesthetist.

Dr. Arthur A. Thibodeau [17] quoted an incidence of 10 per cent. of infection in Otto Hermann's series of compound fractures. He felt that antibiotics were not the answer; there was a new strain of coagulase-positive *Staphylococcus aureus* which was resistant to the usual antibiotics. He stressed the importance of first aid and the treatment of shock, since shock, if long present, may lower tissue resistance and allow infection to develop which would not otherwise occur. He suggested the term "loose-closed treatment" as a good name for delayed closure.

Management of Patients with Pathological Fractures. Dr. Robert Lee Patterson, Jr.[18], and Dr. Sidney W. Eichenholtz [19] emphasized that in pathological fractures, a feeling of hopelessness is not justified despite the progressive deterioration of a patient obviously dying of an incurable cancer. Their paper dealt with the management of fractures occurring at the site of bone metastases; they noted that symptoms of localized pain and swelling were usually present at the site of bone metastases, prior to the time of fracture. In every case, the patient was cognizant of the specific time of increased pain when the fracture actually occurred. Regardless of the source of primary tumor, they felt that the fracture should be cared for. Treatment is to be in the form of (1) an ablation, as in excision of a fractured neck of the femur or as in excision of a thumb with a metastatic growth of the first metacarpal; (2) by plaster fixation; and (3) by internal fixation with screws, as in some oblique fractures of the humeral shaft, or by a Jewett-type nail in intertrochanteric fractures. Lastly, they demonstrated the use of intramedullary pins in fractures of the shaft, and especially in metastatic lesions of the shaft prior to the fracture. No spread of the metastatic growth could be detected along the nail track. The intramedullary nail did not prohibit the use of roentgen therapy locally over the metastatic lesion. This presentation of treatment by preventive nailing in lesions of the shaft of long bones was interesting; the authors showed roentgenograms illustrating healing of the local lesion both following fracture and following preventive nailing. Many of these patients lived long periods of time in comfort following the care of the fracture.

In the discussion by Dr. Paul C. Colonna [20] and Dr. Robert A. Murray [21], it was brought out that education of the physician is necessary to help many of these patients. Many doctors do not know that these fractures will heal in spite of metastatic malignancy. Plates and screws in fractures of the long bones are not as satisfactory as an intramedullary nail and are only a little better than plaster support, except in treatment of the rare spiral-type fracture. Plaster jackets, in compression fractures of the spine, will relieve pain. Many metastatic lesions of the spine fail to be identified even in adequate lateral roentgenograms. The diagnosis then is not appreciated by the physician, because he has no concept of how the pathological tissue has eaten out the bone trabeculae. Adrenalectomy has been helpful in relieving the pain of some of these patients.

Division of the Tibial Collateral Ligament for Removal of the Medial Meniscus from the Knee Joint. Dr. Julius S. Neviaser [22] reported on seventy-two patients in whom the collateral ligament had been divided transversely at the joint level for removal of menisci. Four of these were divisions of the fibular collateral ligament and sixty-eight were of the tibial collateral ligament. His experience with this surgical procedure had convinced him that the knees were not impaired by the surgical approach. Tavernier ("Resultats Éloignés d'une série de 73 méniscectomies". *Bulletin et Mémoires de la Société Nationale de Chirurgie, Paris,*

[16] 150 East Broad Street, Columbus 15, Ohio.
[17] 30 Bennet Street, Boston 11, Massachusetts.
[18] 63 East 91st Street, New York 28, N. Y.
[19] 130 West Kingsbridge Road, Bronx 68, New York.
[20] 3400 Spruce Street, Philadelphia 4, Pennsylvania.
[21] 1110 North Eighth Street, Temple, Texas.
[22] 1918 K Street, N.W., Washington 6, D. C.

59: 1194–1196, 1933.) reported seventy-three meniscectomies in which he had made a transverse incision with section of the medial ligament. Monod ("Arrachement de la corne postérieure du ménisque interne. Extirpation de la totalité de ménisque par l'incision latérale en L". *Bulletin et Mémoires de la Société Nationale de Chirurgie, Paris,* **58:** 1594–1595, 1932.) and Cadenat ("Les voies de pénétration des membres". Éd. 2. Paris, G. Doin et Cie, 1948.) also had suggested the sectioning of the ligament for complete removal of the cartilage. Aufranc (personal communication), in 1953, had recommended releasing the origin of the ligament from the femoral condyle for better visualization and easier removal of the menisci. The author had accidentally discovered the ease of exposure when he had been forced to divide the medial collateral ligament in a difficult case of a torn meniscus which he could not remove through the standard incision. He now advocates a transverse slightly curved skin incision at the level of the knee joint to give exposure to the medial collateral ligament. After a small transverse incision has been made in the medial patellar retinaculum just forward of the anterior border of the ligament, a thin periosteal elevator is passed through this opening to come out behind the posterior border under the medial collateral ligament immediately above the attachment of the meniscus. The ligament is divided just above the meniscus, and the meniscus is then excised. The ligament is sutured by interrupted chromic mattress sutures, and a plaster cylinder is applied which holds the knee in extension and adduction. The patient may then walk and bear weight the following day, although some patients prefer to wait a day longer. The plaster cylinder is removed in about three weeks, the average time being 18.8 days. Some of his confreres had not been in the habit of using plaster immobilization, but had begun active motion immediately. The author advocated the usual active exercises and physiotherapy following removal of the plaster cylinder. He had not noted any hemarthrosis of the knee or swelling of the foot and ankle. Of the seventy-two patients, twelve had posterior-segment tears of the meniscus, which could not have been visualized through an anterior compartment incision alone. Private patients returned to work in an average of 6.2 weeks, while compensation patients required an average of 8.1 weeks. In three cases, instability of the knee was noted at follow-up examination; this was corrected later by physiotherapy and active muscle exercises. In six patients there was minimal quadriceps atrophy. Dr. Neviaser stated that the advantage was the complete removal of the entire meniscus with minimal trauma. Cystic menisci are easily removed. Torn posterior horns of menisci could be completely removed and some tears of the cruciate ligaments could be visualized which could not be seen from the front.

The discussion by Dr. H. Relton McCarroll[23] and Dr. Roy I. Peck[24] brought out the fact that the exposure was excellent but that they still preferred to use the standard incisions and to preserve the collateral ligaments whenever possible. They believed it was heartening to know that one could sever this vital structure and still have a stable joint. They thought it would be a valuable addition to surgical technique but would not accept it as a routine procedure. They noted that Fisher (*Internal Derangements of the Knee Joint.* London, H. K. Lewis and Co., Ltd., 1924.) and Cave ("Combined Anterior-Posterior Approach to the Knee Joint". *The Journal of Bone and Joint Surgery,* **17:** 427–430, Apr. 1935.) described curved medial incisions for the exposure of the collateral ligaments. The anterior and posterior joint compartments could then be entered without severing the ligament.

The Role of the Orthopaedic Surgeon in the Treatment of Cerebral Palsy. Dr. Frederic C. Bost[25], Dr. R. Kirkland Ashley[26], and Dr. Warren J. Kelley[27] stated that since the writings of William John Little in the middle of the nineteenth century, much progress has been made in the management of patients afflicted with cerebral palsy. In recent years, an enlightened medical and lay public have joined together to bring about great progress in the treatment of these patients. Progress has been due to the teamwork of many in the professions of education, sociology, and medicine. Impetus has been given to the work by the financial aid provided by the organizations interested in these fields. While teamwork has been of the utmost importance, the authors believe an undue importance and emphasis has been placed on certain aspects of treatment, bringing about a de-emphasis of other important and useful methods of therapy. Because of his background and training in the field of physical exercise, rehabilitation, and the correction of deformities, the orthopaedic surgeon is an important member of the team involved in the care of the patient with cerebral palsy. The first surgical attention given to cerebral palsy was the use of the tenotomy of Delpech, later popularized by Stromeyer and Little. Later, the correction of deformities in the patient with cerebral palsy was made to depend on the transplantation of tendons, the resection of nerves, and arthrodeses of joints. From the beginning, the discriminating orthopaedic surgeon has used all these methods of treatment. They include the use of massage, stretching, and active exercises of the muscles, together with re-education of purposeful movements. In modern times, the list of operations of benefit to the patient includes surgery on the upper and lower extremities and is quite extensive in its scope. There are many operations which,

[23] 3720 Washington Boulevard, St. Louis 8, Missouri.
[24] 3400 Spruce Street, Philadelphia 4, Pennsylvania.
[25] 384 Post Street, San Francisco 8, California.
[26] San Francisco, California.
[27] San Francisco, California.

by long usage, have proved ultimately to be satisfactory for the treatment of cerebral palsy. The orthopaedic surgeon familiar with these should make sure that his associates in the treatment of cerebral palsy are also familiar with the beneficial results to be expected from these procedures. It is only by a process of patient re-education that the orthopaedic surgeon can convince his colleagues in the ancillary fields that well chosen operations are of benefit. They drew attention to some ancillary technical personnel, whose training and experience had been restricted to the one field in which they worked. An ignorance of other methods of treatment, combined with inexperience, led them to place a false emphasis on the one type of therapy with which they were familiar. Their unrestricted and often ecstatic enthusiasm for this treatment rapidly spread to others. Because the ancillary worker occupies a peculiarly intimate relationship to the patient, to the parent, and to other technical and lay associates, an unwarranted emphasis has been placed upon the importance of physical therapy in the treatment of cerebral palsy. No qualified physician deprecates the great importance of physical therapy in treatment, but like surgical treatment, it must be considered as a part of the complete program rather than as the whole program. It is essential for those in charge of the program to maintain an attitude of tolerance and broad-mindedness toward all types of treatment. The ideals of treatment are best obtained by grouping the interested specialists into the team. One qualified individual, who is usually the orthopaedic surgeon, should be responsible for the integration of the efforts of the team as a whole. The orthopaedic surgeon because of his specialized training and his knowledge has the important role to play in this respect.

Dr. Sidney Keats [28] felt that some of the widespread dismay that followed poor surgical results in past years could be attributed to a lack of understanding of the general nature of cerebral palsy on the part of some surgeons. To illustrate his point, he cited the complications attendant upon surgery on the handicapped arm in the hemiplegic child if that arm was the inherited dominant arm and if the child had not made a complete "shift" of dominance or handedness to the opposite member. Such children were classified as "incomplete shifts". They showed a high incidence of convulsions, speech disorders, mental retardation, and behavior disturbances. Of eighty-seven hemiplegic children studied, forty-four had been required to shift from the inherited dominant arm to the opposite arm. Fifteen of these had made "incomplete shifts" and in them seizures and emotional and behavior disturbances, with mental retardation and speech disorders, developed. These complications were avoided almost completely by withholding occupational therapy and bracing from the handicapped arm and by directing the therapy to the uninvolved arm only, in order to speed up the completion of the shift. Of significance, too, was the unnoted sensory impairment in the affected arm, upon which surgery had been performed. When sensory disturbances were present, transplantations were notably poor.

Dr. Lenox D. Baker [29], in his discussion, emphasized the importance of surgery as an early measure, so that adequate training programs could be established. He felt it unwise to continue stretching a limb with a stretch reflex, since surgery was indicated in order to release it. He noted the importance of the triple arthrodesis in giving a child a stable platform on which to walk and believed that this should be done early so that training would be more effective. He deprecated the statement and belief of some that no surgery was possible in patients with athetosis. In his great experience, surgery, together with an adequate training program, had been responsible for raising the level of existence of many of these children. Some were able to sit up who formerly could never have done so without surgery and others could be made to walk who previously had been confined to bed or to the wheelchair.

Address of the Chairman of the Section

The Physician and Compensation Patients. Dr. Jesse T. Nicholson [30], the Chairman, addressed the Section, presenting several of the problems that exist between a compensation patient, the insurance adjuster, and the physician. With some humor, these problems were discussed, showing the viewpoint of the three parties concerned. He showed how the physician should handle the varying problems, emphasizing that fewer difficulties would exist if the insurance company were regarded as the responsible guardian of the patient. He believed the family physician should not be left out of the picture, since a compensable accident was but one item in the patient's medical life. Consultation should be requested as freely for compensation patients as for those treated privately, and the same physician-patient relationship should prevail with compensation patients as with other patients.

A proper evaluation of the injury was essential to both the insurance carrier and to the patient. The physician should inform the patient of the recommended disability rating. He believed that a disability evaluation should be included in any hospital training program at the resident level. He advocated adding 23 per cent. to the estimated total period of disability as based on private patients, since compensation patients take longer to return to work, and it was important for the carrier to lay aside necessary funds early to cover this period of disability.

[28] 222 North Wyoming Avenue, South Orange, New Jersey.
[29] Duke Hospital, Durham, North Carolina.
[30] 330 South 9th Street, Philadelphia 7, Pennsylvania.

Whiplash Injuries. Subluxation of the Cervical Spine. Dr. Leo A. Green [31] recommended lateral roentgenograms in flexion and extension, and oblique views, to demonstrate minor subluxations of the vertebrae with whiplash injuries. Early hospital treatment, including traction, a brace, local heat, and massage, had reduced symptoms and minimized late sequelae in his experience.

The discussion was opened by Dr. W. L. Bailey [32] who disagreed with the author, believing there were many other causes of pain in whiplash injuries including damage within the dural canal which did not show in the roentgenograms.

Dr. H. W. Salzer [33], a neuropsychiatrist, suggested another form of treatment. Since September 1953, he had treated over forty patients with chronic neck, shoulder, and arm pain from whiplash injuries by intravenous injections of diphenhydramine. The dosage ranged from fifteen to twenty-five milligrams given slowly, intravenously, once daily, for five or six injections. This was supplemented by a tablet of twenty-five milligrams, given orally, three times a day. The therapy was helpful in relieving muscle spasm in the neck but would be ineffective in the presence of a demonstrable lesion. This treatment had been more effective in his hands than physiotherapy.

Posterior Dislocation of the Shoulder. Dr. Sylvester J. O'Connor [34] and Dr. Albert J. Kacknow [35] reported on sixteen patients with posterior dislocation of the shoulder, six of which were post-convulsive and ten of which resulted from trauma. The patients presented themselves with the arm held in the "Velpeau" position, the forearm being held on the abdomen with the humerus in adduction and internal rotation across the chest. There was a loss of the normal oval contour of the shoulder when viewed from the front or from the lateral aspect. Actually the head of the humerus could be palpated posteriorly. Because twelve of his patients had concomitant fractures of the surgical neck, eight of the total series had been incorrectly diagnosed initially as fracture only, the dislocation not being noted until several days later. Reduction of the dislocation is usually easy, but maintenance of reduction is difficult.

McLaughlin believed that reduction was stable in acute cases in internal rotation and adduction, but opposed to this view were Wilson and McKeever, who felt that wire transfixion was necessary through the acromion into the humeral head for a brief period for adequate fixation in reduction. The authors had found that following the reduction of the dislocation the joint was stable with the arm in external rotation. To hold the arm in this position, they applied a short plaster jacket with a bar extending to a circular arm cast by which the arm was held in 40 degrees of abduction and in 65 degrees of external rotation for a three-weeks' period. Following this, active exercises were begun.

In the discussion by Dr. Frederick M. Smith [36] and Dr. Dana M. Street [37], it was brought out that this injury was frequently misdiagnosed, mistreated, and misunderstood. It forms 3 per cent. of the shoulder injuries, and occurs usually as a result of trauma with the arm in the position of flexion and internal rotation. It is rather frequently seen today as one of the shoulder injuries following shock therapy. Careful inspection of the shoulder with the arm in the Velpeau position will reveal a skin groove, visible anteriorly, and a loss of the prominent dome of the humeral head as seen from the side. On palpation one notes that the head lies posterior to the glenoid. The patient is unable to externally rotate the shoulder. The cleft defect in the humeral head was discussed. The cleft is formed as a compression fracture of a portion of the humeral head as the posterior glenoid rim pushes in the cortical articular surface.

Dr. Neviaser [22] believed that cuff injuries are sometimes associated with these fractures.

Dr. H. Relton McCarroll [23] had repaired a late case by utilizing the teres minor tendon in much the same fashion as the subscapularis tendon is used anteriorly in the Magnuson operation.

Acquired Torticollis in Children and Young Adults. Dr. John S. Donaldson [38] discussed rotatory subluxation in children and young adults between the first and second and between the second and third cervical vertebrae. He showed that in cases of sudden onset of torticollis following minimal injuries, both subluxations occur.

The author explained the occurrence on the basis of the anatomical change in the angle of the facets with growth. Slides were shown to demonstrate this anatomical change, as well as the change in the slant of the facet from a horizontal to a more vertical angle, the more caudad were the vertebrae located in the cervical spine.

In a review of the literature both of these subluxations were recognized as separate entities, but it never seems to have been demonstrated that the two subluxations co-exist. Finally, techniques of x-ray

[31] 114–20 Queens Boulevard, Forest Hills, Long Island.
[32] 501 Delaware Avenue, Wilmington, Delaware.
[33] 868 Doctors Building, Cincinnati, Ohio.
[34] 1313 East Ann Street, Ann Arbor, Michigan.
[35] 1313 East Ann Street, Ann Arbor, Michigan.
[36] New York, N. Y.
[37] Veterans Administration Hospital, Memphis 15, Tennessee.
[38] 121 University Place, Pittsburgh 13, Pennsylvania.

studies were demonstrated, and a plea was made for more effective and prolonged immobilization following reduction of these subluxations.

Dr. Emanuel B. Kaplan [39], in opening the discussion, drew attention to a report by Dr. Robert Lippman in 1953 that a dorsal prominence on the odontoid process can give the appearance of rotation of the first on the second cervical vertebra which is not actual but merely due to the odontoid process seeming to be closer to one side than to the other, thus simulating a subluxation. He stated that the odontoid process was not always symmetrically developed. He mentioned a previous report of his own in which he drew attention to the fact that the articular facets between the occiput and the superior surface of the first cervical vertebra are in line with the transverse processes; the facets between the second and third cervical vertebrae are completely posterior to the transverse processes of these vertebrae.

Dr. J. William Fielding [40] in his discussion expressed doubt that subluxation could be diagnosed by lines drawn on the roentgenograms. He showed slides of roentgenograms of the cervical spines of normal children in whom routine views showed what appeared to be subluxations at the two levels. No true abnormalities existed in these children. He believed that the condition of acquired traumatic torticollis demanded a definite explanation that went beyond simple facet displacement. He believed that spasm of unknown origin fixed the cervical spine in a phase of its rotatory motion.

Meniscus Injuries of the Temperomandibular Joint. Dr. Carroll M. Silver [41], Dr. Stanley D. Simon [42], and Dr. Americo A. Savastano [43], in an excellent demonstration, presented the clinical findings in forty-four patients operated upon for injuries to the meniscus of the temperomandibular joint. The operative technique was discussed and was amply demonstrated by means of colored slides; they had removed the meniscus without removing a segment of the zygoma. It had been rarely necessary to remove the condyle. Transient weakness of branches of the facial nerve had been noted in many patients following operation, but nerve function in each had returned to normal. The straight vertical anterior-auricular incision had been preferred rather than the transverse one. That considerable precaution needed to be taken to avoid injury to the branches of the facial nerve and of the superficial temporal artery was demonstrated.

In the discussion, Dr. David M. Bosworth [44] and Dr. Edward L. Compere [45] pointed out the excellence of the presentation and the authors were applauded for their honesty and for their industry in collecting such an unusual series of cases.

Forty-four operative cases might seem unusual; the authors had, however, been working in conjunction with dentists and otolaryngologists, and the number of cases thus collected had been extensive. It was clearly shown by the excellence of the results that in competent and experienced hands surgery was justifiable.

Intra-Articular Osteocartilaginous Joint Bodies: Pathogenesis and Clinical Management. Dr. J. Vernon Luck [46] noted that, while it is well known that the synovial membrane can create osteocartilaginous joint bodies, it was little known that there was another entity in which joint bodies are created at the junction of the synovial membrane and the articular cartilage. The pathogenesis of these osteochondromata was different, and their performance in the joint was different. They arose from the junction of the synovial membrane and the articular cartilage. They appear often as small pearly studding at the junction of the articular cartilage and the synovial membrane. They tend to group together into clusters when they fall off. They tend to come in crops, which form for a time, fall off separately, group together into clusters, and become reattached at some other location in the joint. Fairly soon thereafter, a new crop of these will form elsewhere in the joint. The bony element in them dies unless they become reattached, but the cartilage part may grow, gaining nourishment from the joint fluid. The third type of osteochondroma arises directly from the articular surface of the joint and by growing outward may destroy and disrupt the joint function. These latter erratic osteochondromata grow by enchondral ossification and need, in order to be removed, to be shaved off flush with the articular surface. He demonstrated some of these in the knee joint and in the ankle joint which had caused gross disturbance and complete dysfunction of the joint.

In the discussion, Dr. George Inge [47] and Dr. Carter R. Rowe [48] noted the unusual nature of these osteochondromata arising from the articular surface. They felt that the classification reported was a logical one, since the osteochondromata had been placed under the miscellaneous term of "joint mice". They wondered where chondromalacia of the patella fitted into the classification. Dr. Luck emphasized that, if the

[39] 1001 Grand Concourse, New York 52, N. Y.
[40] 742 Park Avenue, New York 21, N. Y.
[41] 225 Waterman Street, Providence 6, Rhode Island.
[42] 225 Waterman Street, Providence 6, Rhode Island.
[43] 205 Waterman Street, Providence 6, Rhode Island.
[44] 742 Park Avenue, New York 21, N. Y.
[45] 720 North Michigan Avenue, Chicago 11, Illinois.
[46] 1930 Wilshire Boulevard, Los Angeles 2, California.
[47] 603 West Main Avenue, Knoxville 1, Tennessee.
[48] 264 Beacon Street, Boston 16, Massachusetts.

loose bodies were synovial in origin, synovectomy might be indicated in recurrent cases. If, however, it was chondrosynovial in origin, synovectomy certainly was not indicated. The purpose of his paper was, however, to show that one could often note the type of loose body in the roentgenograms and tell its origin and thus know the therapy indicated. The articular type of osteochondroma demanded early operative intervention and excision before it disrupted the joint.

Arthropathy in the Hemophiliac Patient. Dr. A. F. De Palma [49] and Dr. J. N. Cottler [50] presented findings from the Hemarthropathic Clinic of the Jefferson Medical College which provided considerable material for the study of hemophilic arthropathy. A hundred and seventeen hemophiliacs were the basis of this study. He noted the various roentgenographic features of the disorder. The most significant early roentgenographic findings are the increased density in the synovial and capsular tissues, and cystic areas in the subchondral and cancellous bone. In more advanced cases the bone ends are broader than the normal and the joint space is narrowed. Collapse of the bony trabeculae occur later, producing angular deformities of the joint. Spurring of the tips of the oleeranon, the coronoid process of the ulna, the poles of the patella, and the tibial spines are common findings. Broadening and deepening of the intercondylar notch of the femur is visible in the roentgenograms of late cases, together with pronounced subchondral sclerosis adjacent to the joint. Some patients exhibited rapid increase in the size of the osteogenic growth center, particularly in the epiphyses of the radial head. Overgrowth of the epiphyses in all of their dimensions was a common finding and was responsible for the characteristic knobbiness so frequently exhibited in hemophilic joints. Colored slides demonstrated the microscopic findings. The articular surfaces were usually stained a chocolate color from hemorrhage. No hyaline cartilage remained in the joint, and the subchondral bone was seen to be eburnated and peppered with crater-like defects. The synovial membranes were thickened and oedematous, with numerous fine villae. Microscopically, the articular cartilage was fibrillated, fragmented, and thin. He noted the presence of Weichselbaum's lacunae, with fragmentation of the cartilage overlying the lacunae, which accounted for the pitting visible grossly in the joints. He noted that the hemophiliac is born with normal joints, but that the repeated hemorrhages produce the subsequent changes. He attempted to grade the hemophiliac according to the severity of the joint lesion, *Grade 1* being the earliest form of arthritis encountered without contracture. In *Grade 2* minor contractures are present, with slight bony enlargement of the epiphyses and knobbiness of the joint; in *Grade 3* fixed deformities are present in more than one place. Here the knee might exhibit flexion and valgus contracture, and external rotation contractures, with marked thickening of the joint structures and knobbiness of the bone ends. *Grade 4* included a markedly severe contracture with fibrous ankylosis, damaged epiphyses, and bony sclerosis in the roentgenograms. He favored the aspiration of blood from a fresh hemorrhage into the joint and advocated one cubic centimeter of hydrocortisone being injected into the joint at the same time. Their clinic did not like to use hyaluronidase in the joint, since they felt it took a long time for the joint tissues to return to normal following its use. Pressure dressings were applied after aspiration and the injection of hydrocortisone. Care was taken to prevent flexion deformity of the joint, so that bracing was sometimes necessary. In exceptional cases, surgery had been performed on some of these patients, but this could only be done if the patient's blood was in *Grade 1* or *Grade 2*. He stated that this grading had been carefully worked out and that the method of grading would appear in publication within the next month or two.

In the discussion Dr. J. I. Kendrick [51] and Dr. Lee Ramsay Straub [52] acknowledged the extensive work done by the authors. However, they felt that surgery was contra-indicated except in the most exceptional instances. In massive hemarthrosis, they agreed that aspiration was desirable after some attempt had been made to correct a blood defect by the infusion of whole blood or quick-frozen type specific plasma.

Early Diagnosis and Prognosis of Non-Union of the Femoral Neck with the Aid of Laminography. Dr. Norman J. Rosenberg [53] and Dr. Rudolph S. Reich [54] showed conventional anteroposterior and lateral roentgenograms of nailed hips, in which it was difficult to tell the degree of apposition of the fragments throughout the extent of the fracture site. These same hips had been studied by laminograms which gave information at one-centimeter intervals across the area of the fracture site. When the postoperative laminograms of the fracture site showed almost total apposition of the fragments, he believed non-union would not occur. This, however, was uncommon; most cases showed apposition of about 60 per cent. or more. When apposition was less than 60 per cent. non-union was common.

In the discussion, Dr. Nicholas J. Giannestras [55] expressed the belief that, although laminograms

[49] 248 South 21st Street, Philadelphia 3, Pennsylvania.
[50] Jefferson Medical College, Philadelphia, Pennsylvania.
[51] 2020 East 93rd Street, Cleveland 6, Ohio.
[52] 535 East 70th Street, New York 21, N. Y.
[53] 10515 Carnegie Avenue, Cleveland 6, Ohio.
[54] 10515 Carnegie Avenue, Cleveland 6, Ohio.
[55] 1001 Carew Tower, Cincinnati 2, Ohio.

might be of help in some few cases, more information could be obtained from properly taken views using a rotating anode with a fine focal exposure. He agreed that the conventional anteroposterior and lateral views were not sufficient to show all of the circumference of the cortex at the fracture site. The hip should be rotated from external rotation into internal rotation to demonstrate the cortical margins well.

DR. JOHN ROYAL MOORE [56] felt that the conventional roentgenograms showed alignment and position of the fracture site but agreed with the authors that apposition or contact at the fracture site was best demonstrated by laminograms.

Fractures of the External Humeral Condyle. DR. HENRY MILCH [57], in discussing fractures of the external humeral condyle in children, recognized two separate and distinct abduction types which could be noted roentgenographically. In Type I, the fracture passes through the capitellum lateral to the trochlear ridge on the inferior articular surface of the humerus. In the children's roentgenograms, the ossification center of the capitellum may be visible, but in most the cartilaginous part of the trochlea is not visible. In the Type I fracture, the capitellum may be displaced slightly upward and laterally, but the elbow joint is stable because the ulna is held firmly in the saddle-shaped curved surface of the trochlea. In the Type II fracture, however, the fracture line passes medial to the trochlear ridge and the whole outer fragment is displaced laterally. The ulna then becomes dislocated from its normal trochlear articulating surface. These roentgenograms show the angulation at the joint line. He did not believe the medial collateral ligament need be torn for this dislocation to occur. He showed late roentgenograms of patients following healing of the fracture-dislocation. Many believe this deformity is due to growth disturbance, but the deformity is primarily one that results from a modification of the ulna in response to the dislocation. In it the trochlea seems larger and overgrown. From the adult skeleton (not the cadaver of a child) the author noted that the Type I fracture treated in flexion gave no stability to the capitellum fragment. On extension of the elbow, however, the capitellum fragment was supported by the olecranon in the fossa. He wondered if the Type I fracture could be treated successfully in full extension. No beneficial support was offered by the ulna in the Type II fracture. This fracture demands open reduction. In the sequelae of cubitus valgus, which result from improperly treated fractures, the Type I fracture lends itself well to an angulation osteotomy by resection of a wedge of bone. The Type II fracture cannot be corrected by this method, however, but has to have a lateral transposition of the forearm or lateral displacement of the condylar fragment to obtain axial alignment of the bones.

In the discussion DR. ROBERT J. JOPLIN [58] and DR. ROBERT E. INGERSOLL [59] pointed out that these two fractures had been noted in the literature for many years. Dr. Joplin believed, with Dr. Fred Smith, that in the Type I fracture the medial collateral ligament was usually torn. They both believed that the roentgenograms were not sufficient to show specifically in all cases whether the fracture was of the Type I or the Type II variety. The hallmark of the Type II fracture was certainly the ulna dislocation. The question was raised whether it was not possible for the ulna to be dislocated in some Type I fractures. Open reduction was considered to be the treatment of choice.

[56] 3401 North Broad Street, Philadelphia 40, Pennsylvania.
[57] 225 West 86th Street, New York 24, N. Y.
[58] 1180 Beacon Street, Boston 46, Massachusetts.
[59] 520 Commonwealth Avenue, Boston 15, Massachusetts.

News Notes

The next Annual Meeting of the **Western Orthopedic Association** will be held at the Reef Hotel, Honolulu, Hawaii, from November 7 to 10, 1955, under the presidency of Dr. J. Warren White.

The Second Annual Meeting of the **Orthopaedic Research Society** will be held at the Palmer House, Chicago, Illinois, January 28, 1956.

The next Annual Meeting of **The American Academy of Orthopaedic Surgeons** will be held, under the presidency of Dr. Walter P. Blount, at the Palmer House, Chicago, Illinois, January 28 to February 2, 1956.

The next Annual Meeting of **The American Orthopaedic Association** will be held at the Banff Springs Hotel, Banff, Alberta, Canada, from June 20 to 23, 1956.

The Eighty-third Annual Meeting of the **American Public Health Association** and forty related organizations will be held at the Municipal Auditorium, Kansas City, Missouri, from November 14 to 18, 1955.

American Board of Orthopaedic Surgery. Part I examinations in various centers are to be held in April, 1956. Deadline for receipt of applications is November 30th. They should be made to the Secretary, Dr. Harold A. Sofield, 116 South Michigan Avenue, Chicago 3, Illinois.

The Sixty-second Annual Convention of the **Association of Military Surgeons of the United States** will be held November 7, 8, and 9, 1955, in the Presidential Ballroom of the Statler Hotel, Washington, D. C. For copies of the complete program write to Stuart E. Womeldorph, Executive Secretary, Suite 718, New Medical Building, 1726 Eye Street, N.W., Washington 6, D. C.

The Council of the Royal College of Surgeons of England has announced that Dr. Loyal Davis, Chairman of the Department of Surgery at the Northwestern University Medical School, has been awarded Honorary Fellowship.

Dr. Davis, a Regent of the American College of Surgeons and editor of *Surgery, Gynecology and Obstetrics* is internationally known for his work in surgery of the nervous system.

Dr. Frederick W. Rhinelander, formerly of San Rafael, California, has been appointed Associate Professor of Orthopaedic Surgery at Western Reserve School of Medicine, Cleveland, Ohio, the appointment to be effective as of July 1, 1955. Dr. Rhinelander will be Chief of Orthopaedic Surgery at the City Hospital, Cleveland.

The Eleventh Annual Meeting of the **American Society for Surgery of the Hand** will be held at the Palmer House, Chicago, Illinois, on Friday, January 27, 1956. The tentative program is as follows:

Osteogenic Sarcoma in the Hand. Dr. Robert E. Carroll, New York, N. Y.;

Selective Treatment of Dupuytren's Contracture. Dr. Julian M. Bruner, Des Moines, Iowa;

Spontaneous Rupture in Extensor Digitorum Tendons Related to Various Arthritides. Dr. Lee Ramsay Straub, New York, N. Y.;

Tardy Median Palsy, Its Etiology, Early Recognition, and Treatment. Dr. Bland W. Cannon, Memphis, Tennessee;

Perilunar Dislocations. Dr. Carruth J. Wagner, Staten Island, New York;

What is a Good Result in Tendon Surgery? Dr. Robert H. Clifford, Detroit, Michigan;

Method of Treating the Hands of Rheumatoid Arthritis. Dr. Daniel C. Riordan, New Orleans, Louisiana;

Title unannounced. Dr. Thomas W. Stevenson and Dr. David M. Ju, New York, N. Y.;

Replacement of Multiple Metacarpal Loss by Means of Single Iliac-Bone Graft. Dr. Julian M. Bruner, Des Moines, Iowa;
The Surgical, Social, and Economic Aspects of a Unit Hand Injury. Dr. William Metcalf and Dr. William Whalen, New York, N. Y.

The meeting of the **Tri-State Orthopaedic Society** is to be held in Indianapolis, Indiana, October 28 and 29, 1955.

The headquarters for the meeting will be the Marott Hotel in Indianapolis and the Scientific Program will be conducted in the Clinical Building of the Indiana University Medical Center.

The program is as follows:

FRIDAY, 28 OCTOBER 1955

8:45 A.M. Registration
9:00 A.M.: Welcome, Dr. John D. Van Nuys, Dean, Indiana University School of Medicine.
Bunions: The Splay-Foot Operation, Dr. Palmer Eicher;
Treatment of Plantar Keratosis, Dr. William Norman;
Pes Cavus: Plantar Muscle Denervation, Dr. Malcolm Brahms;
Switch Operation: Paralytic Feet, Dr. Sam Davis;
Grice Operation: Paralytic Valgus, Dr. Harvey Sigmond;
Overlapping Fifth Toe, Dr. Frank Teague;
Diabetic Gangrene: Toes and Feet, Dr. Henry Tanner.
2:00 P.M. Primary Fusion in Thoracic Spine Fractures, Dr. Harry Kitterman;
Fractures of the Vertebrae, Dr. R. Manning;
Cervical Spine Fusion—Indications, Dr. J. Neill Garber;
Calvé's Disease, Dr. John Crawford;
Osteitis Pubis, Dr. Lowell Thomas;
Torticollis, Dr. William Franklin;
Pseudohypoparathyroid Disease, Dr. W. Miller;
Paralysis of Hip Abductors, Dr. Robert Kinzel.

SATURDAY, 29 OCTOBER 1955

9:00 A.M. Early Motion Program in Fractures Involving Joints, Dr. Hugh Williams;
Posterior Surgical Approach to the Hip, Dr. Thomas Horwitz;
Bone Tumors of the Phalanges of the Hands and Feet, Dr. John White;
Cast Syndrome, Dr. Edward Schaffer;
Cerebral Palsy: Surgical Procedures, Dr. Carl Martz;
The A. B. C. Trip (1955), Dr. Charles Gregory;
To Be Announced, Dr. Reid Keenan;
To Be Announced, Dr. Donald McCartney.

The Institute for the Crippled and Disabled makes preliminary announcement of a second training program designed to prepare people in rehabilitation for top-level positions of coordination and administration in rehabilitation centers.

The proposed starting date for the seven-month course is December 1, 1955. Applications received by October 15th will be given preference. Final determination on conducting the course will be made by October first.

Persons now engaged in rehabilitation center supervision and administration, and those who have commitments for this type of employment, will be given priority for enrollment.

The training program is designed to meet an urgent need for people equipped to administer and coordinate the complex operations of a comprehensive rehabilitation center which specializes in the problems of the very seriously handicapped.

Applicants for the course should have had at least three-years' experience in such fields of rehabilitation as: health council groups, public health administration, personnel administration, vocational rehabilitation, medicine, occupational therapy, physical therapy, speech therapy, counseling psychology, social work, crippled children services, hospital or welfare institutional administration, and special education.

The training will begin with an initial period at the Institute for the Crippled and Disabled, during which the trainees will be given basic orientation in rehabilitation center management, as well as indoctrination in the relationships of the many professional disciplines which comprise the modern rehabilitation center.

Following this, each trainee will receive three on-the-job training sessions at selected rehabilitation centers throughout the country. Between each session, the trainees will return to the Institute for evaluation

of their experiences and further instruction in the administrative and management areas of rehabilitation center operation.

Trainees will receive a stipend of $250.00 per month for the seven-month period, in addition to round-trip travel expenses from the Institute to the places of on-the-job training. All other expenses will be borne by the trainees.

Except in cases of unusual qualification, trainees must be between thirty and fifty years of age.

A preliminary announcement of the training program has been published by the Institute. Copies and additional information may be had on written request to the Director, Institute for the Crippled and Disabled, 400 First Avenue, New York 10, N. Y.

KAPPA DELTA AWARD

A prize of $1,000.00, donated by the **Kappa Delta Sorority,** is offered annually by The American Academy of Orthopaedic Surgeons for the best research related to orthopaedic surgery and performed by an American citizen in the United States.

Selection for the current year will be made from publications after January 1, 1953, or research presented to the Committee on Scientific Investigation of The American Academy of Orthopaedic Surgeons before November 1, 1955.

Researchers interested in competing may secure information from the Chairman of the Committee on Scientific Investigation of The American Academy of Orthopaedic Surgeons, Dr. Paul R. Lipscomb, 200 First Street, S.W., Rochester, Minnesota.

The **New Jersey Orthopaedic Society** has announced that it will make an award annually of $100.00 in cash for the best original paper in the field of orthopaedic surgery by an intern or resident (in any field) in a New Jersey hospital. The paper may cover any aspect of the field, such as pathogenesis, pathology, diagnosis, or treatment. The work on which this paper is based must have been done during, and completed not later than six months after, internship or residency in a New Jersey Hospital. For the current award the paper should be submitted to the secretary of the Society, Dr. Arthur S. Thurm, 533 West State Street, Trenton 8, New Jersey, not later than January 15, 1956. The award will be announced in sufficient time to permit inviting the winner to present his paper personally at the Spring Meeting of the Society.

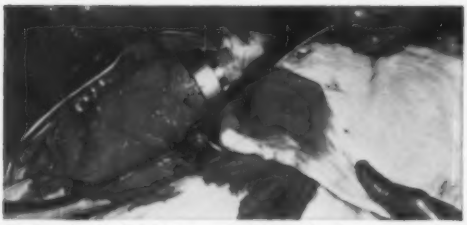
The radiograph indicated surgery. A classic arthroplasty followed . . . color photographs show steps.

PARTNERS in teaching and research... radiography and photography

1. The greater trochanter has been osteotomized and retracted —the hip capsule exposed.

Here are reproduced: first, what radiologist and surgeon saw; then color photographs of the arthroplasty which followed. A final radiograph shows details of the completed surgery. Truly, radiography and photography work hand in hand.

Kodak



2. Template is fitted to prepare for prosthesis.

5. The hip has been reduced.

3. The new socket has been made.

6. Radiograph of completed surgery.

4. Femoral head prosthesis is inserted.

Conclusion: In the field of surgery, radiography and color photography, working together, perform an invaluable service. Between them, they record both the invisible and visible—retain the details of each case for study and discussion during the months and years to come.

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Simplest, because with the new TELFA Sponge-Pad, one dressing is all you need—dressings are changed in seconds—labor costs cut in half.

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Medium Curved No. 4171 B

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No. 436 C 1/4" x 4" SQUARE HONE 2.00

The McKeever type cartilage knife is designed to perform for the surgeon with simple quick-cutting precision. The points of the razor sharp V cutting blade are tear-drop shaped to protect against cutting out. Full tempered stainless steel. Usually sold in sets. The 1/4" square hone provided, when at the proper angle, exactly sharpens the edges. Lubricate the hone with oil or water for a hone-sharp edge on your cartilage knife.

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The 1/4" diameter ROUND HONE is selected to sharpen the Downing Cartilage Knife and the 1/4" Jewett Gouge. It may also be used to sharpen all larger sized Jewett Gouges. However, this same round hone is available in the sizes 5/16"x4, 3/8"x4 and 1/2"x4 at the same price.

No. 436A

No. 436B

No. 436C

No. 436D

Here is a combination set of fine-grained sharpening stones for honing your surgical instruments.

Set of four shown above, No. 436 ..... $9.50

PRICED INDIVIDUALLY:

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No. 436B	2.25
No. 436C	2.00
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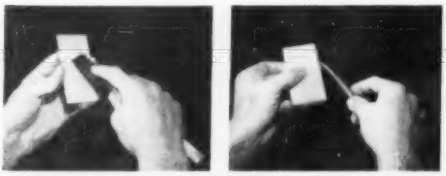
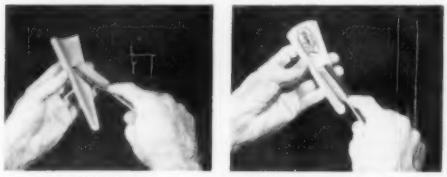
No. 436S, above Hones in canvas sterilizing case $10.50



This fine grained SLIP STONE has two flat faces for honing any flat cutting edge such as a flat chisel or osteotome. Also, it has two rounded edges; one fits a 1/8" and larger diameter and the other edge fits a 3/16" and larger diameter. The 3/16" edge sharpens the 3/16" Jewett Gouge. Dimensions 1¾"x4½"



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No. 436E COMBINATION SHARPENING STONE (6"x 2"x1") One coarse grit side and one fine grit side for general purpose honing. $3.50 ea.

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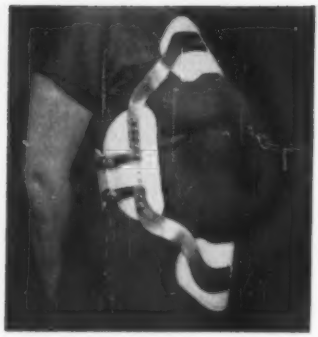

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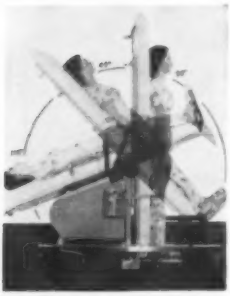

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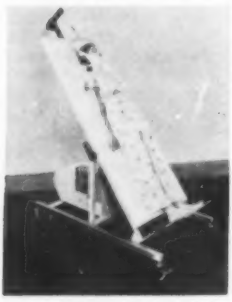

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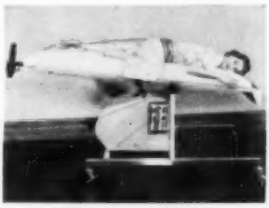

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$155.00 F.O.B. Chicago,

REFERENCES:

Hipps, H. E., "An Evaluation of Certain Non-Operative Methods Used in the Treatment of Cerebral Palsy, "JOUR. OF BONE & JOINT SURG.," July, '48

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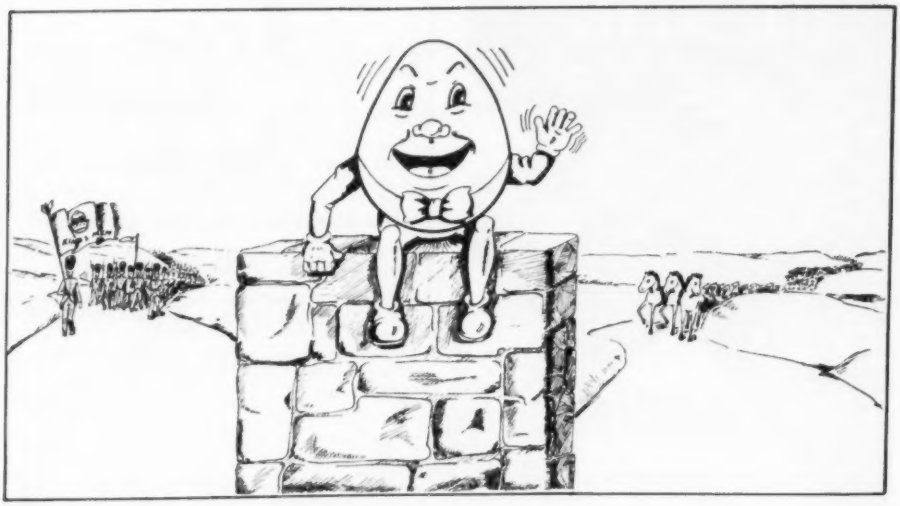

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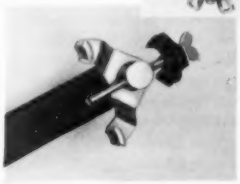

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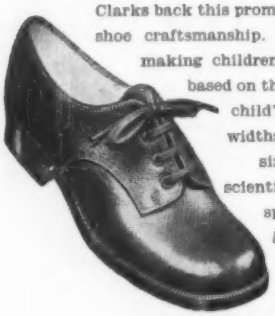
Clarks promise freedom from all foot troubles caused by footwear, if from babyhood none but Clarks shoes are worn, fitted by Clarks Footgauge.



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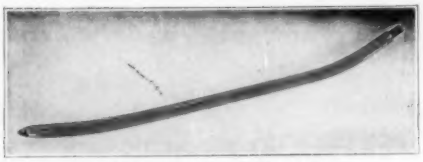
LOTTES TIBIAL NAIL



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Tibial Nail diameters: 5/16" and 3/8"

18-8 SMo Stainless Steel nail made in ½ inch lengths from 9 to 14½ inches.

The triflange nail is also available for femur, humerus, radius, and ulna.

The driver and extractor can be used with any of the triflange nails.

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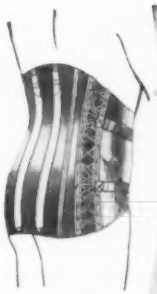

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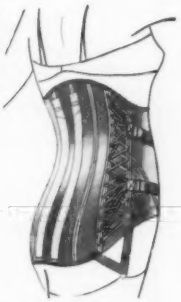

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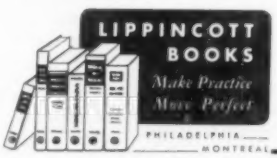

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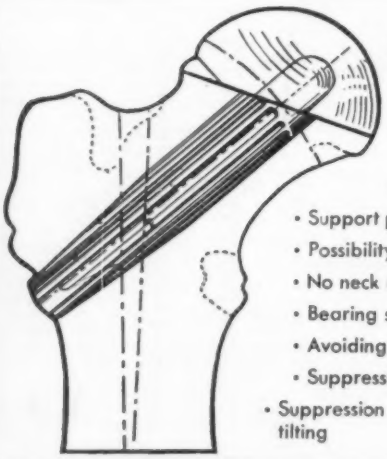

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